

***Final Sampling and Analysis Plan
Volume I: Field Sampling Plan***

***Waukegan Manufactured Gas
and Coke Plant Site
Waukegan, Illinois***

Prepared for North Shore Gas Company

***Under the Administrative Order on Consent Re: Remedial Investigation and
Feasibility Study for the Waukegan Manufactured Gas and Coke Plant Site
Waukegan, Illinois***

October 24, 1991

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FIELD SAMPLING PLAN
WAUKEGAN MANUFACTURED GAS AND COKE PLANT SITE

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SECTION 1

INTRODUCTION

1.1 PURPOSE

The Draft Field Sampling Plan (FSP) has been prepared as a supporting document to the Draft Work Plan for the Remedial Investigation/Feasibility Study (RI/FS) (Barr, 1991a) for the Waukegan Manufactured Gas and Coke Plant Site (WCP), Waukegan, Illinois.

The FSP provides guidance for field activities by specifying the sampling and data-gathering methods to be used. The FSP is one element of the Sampling and Analysis Plan (SAP). The other element of the SAP, the Quality Assurance Project Plan (QAPP), describes the field and laboratory Quality Assurance/Quality Control (QA/QC) procedures for the collection and analysis of soil and water quality samples collected at the WCP site (Barr, 1991b). The data quality objective (DQO) development process is described in the QAPP (Barr, 1991b).

The field work associated with the RI/FS at the WCP site will be conducted in two phases. Phase I activities have been designed primarily to provide preliminary screening information about source areas and groundwater conditions. The results of Phase I will then be used to focus the design of a larger, more complete Phase II investigation. The conceptual design of the phased approach is discussed in the following paragraphs. The FSP specifies the methods to be used for activities conducted in each phase of investigation.

Phase I will involve the investigation of the site facility foundation locations and the preliminary delineation of the lateral extent of surficial contamination. Monitoring wells will be installed and groundwater elevations measured to make a preliminary determination of groundwater flow directions at the site. Soil and groundwater samples will be collected and analyzed in order to make a preliminary characterization of soil and groundwater quality at the site. Once Phase I RI tasks are completed, a Phase I Technical

Memorandum will be prepared that summarizes the data collected. This information will be used to focus sampling and analytical activities in Phase II.

Phase I field activities will include: survey of site ecology, soil sampling of background samples; soil sampling of surficial soils; test trench installation; pilot boring installation; soil sampling for description and geologic interpretation; soil sampling for field screening and laboratory analyses of soil quality; monitoring well and piezometer installation; water quality sampling and analyses; water level measurements; hydraulic conductivity testing; and surveying for location and elevation of site structures, test trenches, pilot borings, piezometers, and monitoring wells.

Phase II of the investigation will involve confirmation of the horizontal extent of soil contamination determined in Phase I and delineation of the vertical extent of soil contamination. Phase II will also involve a characterization of site geology and stratigraphy; delineation of the extent and nature of groundwater contamination; and characterization of the geotechnical and hydrogeologic properties of the site soils. Locations for Phase II activities will be proposed in the Phase I Technical Memorandum.

Phase II field activities will include: soil boring installation; soil sampling for description and geologic interpretation; soil sampling for field screening and laboratory analyses of soil quality; soil sampling for engineering parameters and remedial alternative screening requirements; monitoring well installation; water quality sampling and analyses; water level monitoring; hydraulic conductivity testing; and surveying for location and elevation of soil borings and monitoring wells. The proposed schedule for the RI/FS field activities is shown in Tables 1.1-1 and 1.1-2.

SECTION 2

BACKGROUND

This section describes the site location, the existing conditions at the site, and the information known about the geology and groundwater flow directions at the site.

2.1 SITE DESCRIPTION

2.1.1 Site Location

The WCP site is located in the City of Waukegan, Waukegan Township, Lake County, Illinois. Based on a legal description from a real estate appraisal (Real Estate Research Corporation, 1971) the site is located in the northwest quarter of Section 22, Township 45 North, Range 12 East of the Third Principal Meridian. The site is bounded on the north by Pershing Road (Sea Horse Drive), on the east by Pershing Road, on the south by OMC Plant No. 1, and on the west by Waukegan Harbor. The harbor is maintained and operated by the Waukegan Port District. The site is more or less rectangular in shape with a total area of 36.37 acres. The location of the WCP site is shown in Figure 2.1-1.

2.1.2 Existing Site Conditions

The locations of the historical WCP site structures are shown in Figure 2.1-2. The only remaining structure from the former Coke Plant is an office building in the southeast corner of the property and the above-grade tar tank foundation. The office building has been remodeled and is currently used by OMC. The northwest portion of the site is leased by Larsen Marine to store boats and boat cradles. The western portion of the site contains dredge spoils from Lake Michigan which were placed at the direction of the Army Corps of Engineers in 1974 for temporary storage. A tower that is used for OMC product testing is located just southeast of the dredge spoils. Near the product testing tower is an above ground storage tank farm. There are nine tanks ranging in volume from 300 to 20,000 gallons which contain

gasoline, fuel oil, and kerosene. Public parking in the central area of the site has occurred for special events on the Waukegan public beach. In addition, the foundations of several former plant facilities still exist below grade.

2.2 SITE HYDROGEOLOGIC SETTING

2.2.1 Geology

The uppermost deposits at the site are composed of fill. The fill is approximately 2 to 4 feet thick. It varies in composition from fine to coarse, brown to black sand and is mixed with demolition debris (Canonie, 1990a).

The fill is reportedly underlain by a black to brown, fine to coarse sand unit (Canonie, 1990a). Much of this unit at the site may have been disturbed during the harbor construction. It is likely composed of both natural in-place material mixed with other native material that was moved from nearby locations and placed at the site as fill. The unit ranges in thickness up to approximately 10 feet.

Underlying the black to brown sand is a sand unit composed of grey fine to medium sand with some silt. This unit is approximately 15 to 25 feet thick. Near the new slip location, the unit apparently extends to the surface and the black to brown sand unit is absent. Lenses of silty sand are also present within the grey sand unit.

Samples from the majority of soil borings placed in the vicinity of the proposed new slip indicate the presence of a 1 to 3-foot thick sand and gravel unit directly underlying the grey sand unit. Test holes completed in 1927 on the City Waterworks property (located approximately 1,000 feet south of the site) also encountered a gravel unit at the base of the grey sand.

Underlying the gravel (or directly underlying the gray sand where the gravel is absent) is a thick till deposit of grey silt and clay. This unit was also described (in a 1927 test hole located south of the coke ovens) as

being blue and containing clay, stones, and pebbles. The till unit is reported to be approximately 50 to 200 feet thick regionally (Lineback, 1979). At a soil boring located near the new slip construction area, the unit was at least 30 feet thick; its base was not encountered. The boring completed as part of a well installation near the boiler room (prior to 1927) encountered the base of the till at an elevation of approximately 490 feet above mean sea level (MSL). At that location, the till was approximately 40 feet thick.

Underlying the till is a thick sequence of carbonate bedrock units. The only boring deep enough to penetrate into the bedrock was the boring for the Boiler Room well. The top of the "limestone" unit was encountered at an elevation of 490 feet MSL (a depth of 91 feet). The well boring extended 43.8 feet into the limestone and no significant changes in lithology were noted. Regionally, the Racine, Waukesha, Joliet, Kankakee, and Edgewood Formations form the uppermost bedrock unit. Together, these units are reported to be in excess of 500 feet thick.

2.2.2 Groundwater Flow

Limited hydrogeologic studies have been conducted at the WCP site. A groundwater investigation (JRB, 1981) was conducted in the vicinity of the drainage ditch at the OMC Plant No. 2, located north of the WCP site. Additionally, a preliminary groundwater flow model was constructed as part of a risk assessment for construction of the new slip. Groundwater quality data from two nests of monitoring wells installed at the WCP site are available.

Regionally, groundwater generally occurs under unconfined conditions in the unconsolidated deposits and groundwater in the upper bedrock aquifer occurs under confined conditions. Lake Michigan acts as a major regional discharge zone for groundwater. Therefore, groundwater flow in both the surficial unconsolidated deposits and bedrock units in the region is typically toward the lake.

2.2.2.1 OMC Plant No. 2 Site Hydrogeology

Results of the hydrogeologic investigation completed as part of the OMC technical and witnessing case support (JRB, 1981) indicated that shallow groundwater at the site generally flowed to the east toward Lake Michigan; however, several other factors also had some effect in controlling the localized groundwater flow pattern. These included: (1) the water level in a drainage ditch north of the OMC Plant No. 2, (2) precipitation events, (3) the presence of the till (silt) below the sandy near-shore lake deposits, and (4) fluctuation of the lake level.

Because the investigation focused on the area north of the OMC Plant No. 2 facility, horizontal hydraulic gradient information is available primarily for flow to and from the drainage ditch. Horizontal hydraulic gradients ranged from approximately 6×10^{-3} feet/foot to the southeast along the western boundary of the OMC Plant No. 2 site, to approximately 8×10^{-3} feet/foot in both a northerly and southerly direction along the drainage ditch. No information about horizontal hydraulic gradients was available for the WCP site which is located south of the OMC Plant No. 2 facility. Vertical hydraulic gradients in the surficial aquifer north of the OMC facility are reported to be in a generally upward direction (JRB, 1981).

Hydraulic gradients between the surficial aquifer and the Silurian bedrock were also reported to be in an upward direction (Canonie, 1989). One of the two piezometers installed into the Silurian bedrock reportedly flowed at the surface. Information on the magnitude of the upward gradient was not included in the Canonie report.

"Baildown" tests (slug tests) were conducted in 22 monitoring wells screened in the surficial unconsolidated materials at the OMC Plant No. 2 site. Hydraulic conductivities ranged from 2×10^{-4} cm/sec to 9×10^{-3} cm/sec (JRB, 1981).

2.2.2.2 WCP Site Hydrogeology

Geraghty and Miller, Inc. (1990) prepared a single layer groundwater flow model of the WCP site. They used the USGS MODFLOW computer code to calculate hydraulic head distributions across the site and groundwater fluxes to the harbor. No site-specific hydrogeologic data were available for actual groundwater flow conditions at the WCP site. Therefore, the model could not be calibrated or validated. Results of the modeling predicted that groundwater flow would be to both Lake Michigan and Waukegan Harbor for the simulated conditions, with the divide located approximately down the center of the peninsula. Computed groundwater flow at the northern and southern boundaries of the site had a more southerly component as compared to computed flow at the center of the peninsula.

2.3 WATER QUALITY

2.3.1 Groundwater Quality

The installation of two nests of monitoring wells on the WCP site were part of the New Slip Soil Investigation. The monitoring wells were installed east of the new slip location. Each nest contained a shallow and a deep well with depth intervals of 12.5 to 17.5 feet for the shallow wells and 23 to 28 feet for the deep wells. Samples obtained from the four monitoring wells were analyzed for phenols and PAHs (Canonie, 1990a).

Results of the chemical analyses performed on the soil samples indicate that phenolic contamination is detectable in the deep wells while PAHs were detected in one of the shallow wells. Detection limits for the PAH analyses of samples from the two deep wells were elevated due to the high concentrations of phenols that were present. The groundwater samples were not analyzed for volatile organic compounds that are commonly associated with coking and coal gasification sites.

2.3.2 Surface Water Quality

Extensive studies have been performed to determine the extent of PCB contamination in the Waukegan Harbor. There are no surface waters on the WCP site, but the western border of the site is the Waukegan Harbor. No sampling has been performed to determine if PCBs have migrated on-site.

2.4 SOIL QUALITY

As part of the New Slip Soil Investigation (Canonie, 1990a), and Supplementary Investigations (Canonie, 1991a) soil borings were placed in and around the location of the proposed new slip. Laboratory analyses performed on these soil borings indicate high concentrations (up to 27,000 ppm) of total PAHs near the southeast corner of the proposed new slip. PAHs were detected in samples collected to depths of 25 feet below the ground surface. The nature and extent of soil contamination is not fully defined since samples from the soil borings were generally not analyzed for PCBs (i.e., for samples from less than 15 feet in depth) or for volatile organic compounds (VOCs).

A study performed by the Illinois Environmental Protection Agency in June of 1989 consisted of the collection and analysis of 10 samples from on-site soil borings. Four of the samples were collected near the by-products recovery area, and one of the samples was taken in the gas production area. The remaining five samples were collected at the northern half of the site. The samples were collected between zero and 6 feet in depth. The samples were analyzed for phenols, PAHs, VOCs, pesticides, and metals. Laboratory analyses of the soil samples showed significant concentrations of PAHs, VOCs, and selected metals. Detected PAH concentrations were highest near the tar storage and by-products recovery area. The sample collected near the thionizer building had elevated levels of arsenic and cyanide. The Thylox system used at the WCP, unlike the wood chip system used at some manufactured gas plant sites, used arsenate compounds and produced thiosulfates and thiocyanates.

SECTION 3
PHASE I INVESTIGATION ACTIVITIES

This section describes the Phase I (Task I) field activities, summarizes the objectives of each activity, and describes the methods used to gather the necessary data. Phase I activities will include: collection of background soil samples for laboratory analysis of soil quality; collection of samples of surficial soils for laboratory analysis of soil quality; test trench excavation, pilot boring installation, soil sampling of test trenches and pilot borings for description and geologic interpretation; soil sampling of test trenches and pilot borings for field screening and laboratory analyses of soil quality; piezometer installation; monitoring well installation; water level monitoring; water quality sampling and analyses; hydraulic conductivity testing; and surveying for location and elevation of site structures, test trenches, pilot borings, piezometers, and monitoring wells. A summary of Phase I sampling activities is presented in Table 3.1-1. The proposed schedule for the Phase I activities is shown in Tables 1.1-1 and 1.1-2.

This section is organized into the following subsections:

- Background Soil Sampling (Subtask I.3)
- Surficial Soil Sampling (Subtask I.4)
- Preliminary Source Area Characterization (Subtask I.2)
- Soil Sampling of Test Trenches (Subtask I.2)
- Pilot Boring Installation (Subtask I.5)
- Soil Sampling of Pilot Borings (Subtask I.5)
- Monitoring Well and Piezometer Installation (Subtask I.5)
- Water Level Monitoring (Subtask I.5)
- Groundwater Quality Sampling (Subtask I.6)
- Hydraulic Conductivity Testing (Subtask I.5)

A subtask number follows each subsection heading in this FSP. The subtask numbers correspond with the subtask numbers used in the Work Plan.

3.1 BACKGROUND SOIL SAMPLING (Subtask I.3)

3.1.1 Soil Sample Collection Objectives

The objectives of the background soil sampling are to:

- Characterize the typical background concentrations of chemical constituents in soils in the surrounding the industrial area; and
- Characterize the typical background concentrations of chemical constituents in soils in local areas thought to be unaffected by industrial activities.

Eight background soil samples will be collected. Samples will be analyzed for the entire Target Analyte and Target Compound Lists; i.e., semivolatiles, volatile organic compounds, metals, cyanide, PCBs, and pesticides. Table 3.1-2 shows the Target Analyte List (TAL) and the Target Compound List (TCL). The proposed locations for background sample collection are shown in Figure 3.1-1.

3.1.2 Background Soil Sample Designation

Soil samples collected for background concentration analysis will be assigned a 4 digit alpha-numeric identifier, according to the following scheme:

First two digits - BS

Digits 3 and 4 - Background sampling location number

For example, the sample collected from the first background sampling location will be identified as BS-01.

3.1.3 Soil Sampling: Procedures and Equipment

Soil sampling of the surface or near-surface soils and/or sediments will be performed using hand equipment. Samples will be collected from 2 to 4 feet in depth. If sampling is conducted in areas where vegetation has been established, leaves, grass, and surface debris will be removed from the area to be sampled using a clean stainless steel spoon or steel shovel. Surface soil samples will be collected using a precleaned, hand-auger and split-barrel and rod sampling assembly. When the soil sample is obtained, it will be packaged immediately.

Sampling procedures and equipment will conform to the Standard Operating Procedure (SOP) for Soil Sample Collection (Attachment 1). Sample Custody will conform to the Standard Operating Procedure for Chain-of-Custody (Attachment 2). Transporting samples to the laboratory will conform to Standard Operating Procedure for Sample Transporting (Attachment 3).

3.1.4 Soil Sample Analyses Methods

3.1.4.1 Laboratory Techniques

Analytical Methods for Volatile, Semivolatile, PCB and Pesticide Samples. Soil samples will be analyzed for volatile, semivolatile, PCB, and pesticide compounds. The analytical methods are described in detail in the QAPP.

Analytical Methods for Metals and Cyanide Samples. Soil samples will be analyzed for metals and cyanide. The analytical methods are described in detail in the QAPP.

3.2 SURFICIAL SOIL SAMPLING (Subtask I.4)

3.2.1 Soil Sample Collection Objectives

In order to characterize surficial soil quality across the site, a series of 17 shallow soil samples will be collected at the locations shown in

Figure 3.2-1. The locations were selected to address areas of the site where potential source areas have not been identified and where other sampling efforts have not been completed. Where possible, a test pit will be excavated with a backhoe to provide visual information at the selected locations. Based on that visual information, sampling points adjacent to the test pits will be selected. At each of these sampling points, a sample will be collected from 2 to 4 feet in depth using a hand auger. Shallow soil borings will be used for sample collection at the three locations in the OMC Plant No. 1 parking lot. Sections 4.1 and 4.2 discuss the installation and sampling of soil borings. Each surficial soil sample will be analyzed for the full scan of target compounds.

3.2.2 Soil Sample Designation

The surficial soil samples will be assigned a four-digit, alpha-numeric identifier according to the following scheme:

First two digits - SS

Digits 3 and 4 - Surficial soil sampling location number

For example, the sample collected from the first surficial soil sampling location will be identified as SS-01.

3.2.3 Soil Sampling: Procedures and Equipment

Soil sampling of the surface or near-surface soils and/or sediments will be performed using hand equipment. Samples will be collected from 2 to 4 feet in depth. If sampling is conducted in areas where vegetation has been established, leaves, grass, and surface debris will be removed from the area to be sampled using a clean stainless steel spoon or steel shovel. Surface soil samples will be collected using a precleaned, hand auger and split-barrel and rod sampling assembly. When the soil sample is obtained, it will be packaged immediately.

Soil sampling procedures will conform to the SOP for Soil Sample Collection (Attachment 1). Sample custody will conform to the SOP for

Chain-of-Custody (Attachment 2). Transporting samples to the laboratory will conform to the SOP for Sample Transporting (Attachment 3).

3.2.4 Soil Sample Quality Screening and Analyses Methods

3.2.4.1 Field Screening Techniques

Four methods will be used in the field to determine evidence of contamination. The methods include: (1) visual examination; (2) oil sheen test; (3) recording of any product or "unnatural" odor; and (4) headspace organic vapor screening. The field screening techniques will conform to the SOP for Field Screening Techniques (Attachment 4).

3.2.4.2 Laboratory Techniques

Analytical Methods for Volatile, Semivolatile, PCB and Pesticide Samples. Soil samples will be analyzed for volatile, semivolatile, PCB, and pesticide compounds. The analytical methods are described in detail in the QAPP.

Analytical Methods for Metals and Cyanide Samples. Soil samples will be analyzed for metals and cyanide. The analytical methods are described in detail in the QAPP.

3.3 PRELIMINARY SOURCE AREA CHARACTERIZATION (Subtask I.2)

3.3.1 Preliminary Source Area Characterization Objectives and Placement

The objectives of the preliminary source area characterization are to:

- Provide data on the locations of historical structure foundations for orientation and preparation of a site map;
- Delineate the lateral extent of surficial soil contamination in areas identified as potential source areas (based on knowledge of site's operational history); and

- Obtain representative samples of soils containing coal tar for laboratory analysis.

Test trenches will be the primary method used at the WCP site for initial source area characterization.

Shallow soil borings will be used to investigate two former ponds identified from aerial photographs. Sections 4.1 and 4.2 discuss the installation and sampling of soil borings. Figure 3.3-1 shows the proposed locations of the shallow soil borings.

The proposed locations and orientations of the test trenches to be installed at the WCP site are shown in Figure 3.3-1. The proposed locations of the trenches are based on information pertaining to the locations and uses of historical plant structures.

3.3.2 Test Trench Designation

The test trenches will be designated by the prefix "TT". The TT (Test Trench) will be followed by a two-digit number that will correspond to the order in which the trench is installed.

3.3.3 Test Trench Excavation

The test trenches will be excavated using a backhoe and will extend from areas of visual contamination or areas of suspected foundations to areas that appear to be clean. If contaminated zones are encountered in a test trench, an additional trench will be placed approximately perpendicular to the original trench to further delineate contaminated areas. The trenches will range in length from approximately 25 to 190 feet and in depth from approximately 3 to 6 feet. Groundwater is expected to be approximately 3 to 6 feet below grade at the site. The test trenches will not generally exceed a depth of more than 1 foot below the water table. The equipment used for digging the trenches, including the backhoe bucket and any other tools, will be cleaned before use and after completion of work.

3.3.4 Test Trench Logging

The test trenches will be photographed and logged as they are placed. Logging will include recording: (1) the final length and depth of the trench; (2) a description of the soil; (3) locations of soil samples collected from the trench, if any; (4) a description and location of foundations encountered, if any; and (5) groundwater level within the trench, if encountered. A copy of the test trench log form is included in Appendix A.

A geologist will describe the soils within each test trench according to ASTM Designation D 2488, Standard Practice for Description and Identification of Soils (Visual - Manual Procedure). This method of soil classification is comprehensive, logical, and provides a consistent level of accuracy. A copy of ASTM Designation D 2488 is included in Appendix B. The geologist will make a preliminary geologic interpretation of the soil based on published information about the geology of the region and site. The soil descriptions will be included on the test trench log form (Appendix A).

Upon completion of the trench logging process and soil sample collection, the soil that was removed from the test trench will be replaced in the trench from which it was removed. The trench areas will be seeded to restore vegetation cover. A 3-foot long wooden stake marked in indelible ink with the trench number will be driven into the ground at each end of the trench to note the location of the trench.

3.3.5 Survey of Test Trenches and Foundations

The test trenches and unearthed foundations will be surveyed to establish both vertical and horizontal location. The vertical elevation will be surveyed relative to Mean Sea Level and accurate to within 0.1 foot. The horizontal locations will be established in relationship to a site grid and will be accurate to within 1 foot.

3.4 SOIL SAMPLING OF TEST TRENCHES (SUBTASK I.2)

3.4.1 Soil Sample Collection Objectives

The objectives of the test trench soil sampling are to:

- Describe and interpret the geology of the surficial sediments; and
- Determine the nature and degree of contamination, if any, present in the surficial soils.

Soil samples will be selected for laboratory analysis to provide a preliminary characterization of soil quality for source areas identified by field screening methods (3.4.4.1). If distinctly different areas of contaminated soils are identified based on field screening, samples will be collected for possible laboratory analysis to characterize each potentially different contaminant type. At least one sample, visually identified as being contaminated, will be selected for analysis from each distinct area of soil contamination as determined by field observations. At least one sample will be collected from the coal fines layer found to be present along the southernmost portion of the new slip and from each of the shallow soil borings in the former pond areas. Additional samples will be selected for analysis from areas that appear to be near the limit of visual contamination and from areas that show no visual evidence of contamination.

Because the nature, extent, number, and continuity of source areas to be identified by field screening methods are currently unknown, the final number of samples to be selected for analysis cannot be projected at this time. At some trenches, more than one sample will be selected for analysis (as described above) to characterize a range of soil qualities identified by field screening. In other cases, several trenches may intersect a single continuous source area, resulting in less than one sample per trench being required to preliminarily characterize soils for that area. Other trenches that show no evidence of contamination during field screening may not have samples selected for further analysis. For planning purposes, it has been assumed that a total of 25 samples will be selected for laboratory analysis.

All samples collected for laboratory analysis will be analyzed for PAHs and VOCs. Approximately 20 percent of the samples will also be analyzed for acid extractables. Samples from trenches located near the thionizer building will be analyzed for cyanide and arsenic. At least one sample of soil with visible coal tar contamination and one sample of visibly contaminated soil from the area of the former creosoting facility will be analyzed for the full scan target compounds (i.e., semivolatiles, VOCs, cyanide, metals, and PCBs). One sample from each of the shallow soil borings in the former pond areas will be analyzed for the full-scan target compounds. One sample from the compacted coal fines layer will be analyzed for the full-scan target compounds and TCLP. Sampling activities are summarized in Table 3.1-1. Table 3.1-2 shows the TAL and TCL.

3.4.2 Soil Sample Designation

Soil samples collected from test trenches will be assigned a 6 digit alpha-numeric identifier, according to the following scheme:

First two digits - TT

Digits 3 and 4 - Trench number

Digits 5 and 6 - The order in which the soil sample was collected from the trench

For example, the second soil sample collected from test trench TT-03 will be identified as TT-03-02.

3.4.3 Soil Sampling: Procedures and Equipment

3.4.3.1 Geologic Analytical Samples

Soil samples will be collected for description and geologic interpretation. Soil samples will be collected from distinct zones observed within each trench for description and geologic interpretation. The soil sample will be collected from the trench using the backhoe. The backhoe bucket will be filled with soil from the trench, then rested on the ground adjacent to the trench. A sample will be collected from the center of the

soil within the bucket using a stainless steel trowel. The geologist will examine and log the samples in accordance with ASTM Designation D 2488, Standard Practice for Description and Identification of Soils (Visual - Manual Procedure). The soil descriptions will be included on the test trench log forms.

3.4.3.2 Quality Analytical Samples

Soil samples from the test trenches will be collected for laboratory analysis by using the backhoe to collect the soil at the designated sampling point. The samples will be removed from the center of the soils in the backhoe bucket using a stainless steel trowel. The sampler, wearing two pairs of sampling gloves, will press the soil into the sample container using finger-pressure unless otherwise stated in the SOP. Sampling procedures and equipment will conform to the SOP for Soil Sample Collection (Attachment 1). Sample Custody will conform to the SOP for Chain-of-Custody (Attachment 2). Transporting samples to the laboratory will conform to the SOP for Sample Transporting (Attachment 3).

3.4.4 Soil Sample Quality Screening and Analyses Methods

3.4.4.1 Field Screening Techniques

Four methods will be used in the field to determine evidence of contamination. The methods include: (1) visual examination; (2) oil sheen test; (3) recording of any product or "unnatural" odor; and (4) headspace organic vapor screening. The field screening techniques will conform to the SOP for Field Screening Techniques (Attachment 4).

3.4.4.2 Laboratory Techniques

Analytical Method for TCLP. At least one soil sample from the coal fines layer will be analyzed using the TCLP method. The analytical method is described in detail in the QAPP.

Analytical Methods for Volatile, Semivolatile, PCB, and Pesticide Samples. Soil samples will be analyzed for volatile, semivolatile, PCB pesticide compounds. The analytical methods are described in detail in the QAPP.

Analytical Methods for Arsenic and Cyanide Samples. Soil samples will be analyzed for arsenic and cyanide. The analytical methods are described in detail in the QAPP.

3.5 PILOT BORING INSTALLATION (Subtask I.5)

3.5.1 Pilot Boring Objectives and Placement

The objectives of the pilot borings are to:

- Obtain soil samples for soil description and stratigraphic interpretation;
- Provide geological information that will aid in the design of the proposed monitoring wells; and
- Obtain soil samples for laboratory analysis, if visual contamination is observed.

Four pilot borings will be placed at the WCP site. The proposed locations of the pilot borings are at the deep monitoring well locations shown in Figure 3.5-1. The proposed pilot boring locations were selected to provide monitoring well locations at the site perimeter for assessing groundwater flow and quality.

3.5.2 Pilot Boring Designation

The pilot borings will be designated by the prefix "SB". The SB (Soil Boring) will be followed by a number that will correspond to the order in which the pilot boring was placed.

3.5.3 Pilot Boring Construction

The pilot borings will be advanced to the top of the gray silt and clay till; a depth of approximately 25 to 30 feet below grade. One pilot boring will extend to bedrock. The pilot borings will be advanced using the 6-1/2 inch inner diameter hollow stem auger drilling technique. Hollow-stem augers have a continuous flight-cutting blade around a hollow metal cylinder. A stem with a plug is ordinarily kept inside the auger barrel to prevent soil from entering. When soil samples are desired, the stem is withdrawn and a sampling tool inserted to the bottom of the borehole. Except when a monitoring well is installed into the borehole, boreholes will be abandoned with neat cement grout following completion. Boreholes will be grouted from the bottom of the hole to the ground surface using a tremie pipe.

Soil cuttings will be spread on the ground in the vicinity of the boring location. Soil cuttings saturated with oil will be containerized and stored on-site.

All drilling equipment, such as hollow stem auger flights, hollow stem auger plugs and downhole tools will be cleaned before use and between boreholes. The drilling equipment will be steam cleaned at the soil boring location. Equipment will be cleaned using one of three methods: (1) steam cleaning, (2) steam cleaning and scrubbing with brush and detergent, or (3) using solvents. Detergent will be used if steam cleaning does not remove all of the oil sheen from the equipment. Solvents will be used to clean equipment if steam cleaning does not remove all visible coal tar. If solvents are needed to clean the drilling equipment, a decontamination pit will be constructed. The decontamination pit will be designed by Barr Engineering Co. and constructed by the contractor. The decontamination pit design will include a low permeability liner installed in either a soil or concrete pit, and equipped with a rinsate water collection system. The decontamination pit design will be provided to the U.S. EPA prior to the pit's construction. The rinse water would be disposed of by: on-site treatment, discharge to the POTW or another approved disposal facility.

3.5.4 Pilot Boring Logging

Each pilot boring will be logged by an experienced geologist. Logging will include recording: (1) the final depth of the pilot boring; (2) the sampling interval; (3) a description of the soil samples and a stratigraphic interpretation; (4) depths of soil samples collected for laboratory analysis, if any; and (5) depth of groundwater encountered, if any. Copies of the soil boring log forms are included in Appendix C.

A geologist will describe soil samples from each pilot boring according to ASTM Designation D 2488, Standard Practice for Description and Identification of Soils (Visual - Manual Procedure). This method of soil classification is comprehensive, logical, and provides a consistent level of accuracy. A copy of ASTM Designation D 2488 is included in Appendix B. The geologist will make a preliminary stratigraphic interpretation of the soil samples based on published information about the geology of the region and site and on information gathered from each pilot boring.

3.5.5 Survey of Pilot Borings

The pilot borings will be surveyed to establish both vertical and horizontal location. The vertical elevation will be surveyed relative to Mean Sea Level and accurate to within 0.1 foot. The horizontal pilot boring locations will be established in relationship to a site grid and accurate to within 1 foot.

3.6 SOIL SAMPLING OF PILOT BORINGS (Subtask I.5)

3.6.1 Soil Sample Collection Objectives

The objectives of the pilot boring soil sampling are to:

- Describe and interpret the stratigraphy of the site; and
- Obtain soil samples for laboratory analysis, if visual contamination is observed.

Representative soil samples from the pilot borings will be collected for laboratory analysis if areas showing significant visual evidence of contamination are encountered or if headspace screening indicates that the sample contains elevated concentrations of VOCs (greater than 100 ppm). These samples will be analyzed for PAHs and VOCs.

3.6.2 Soil Sample Designation

The soil samples collected from the pilot borings will be assigned a 7 digit alpha-numeric identifier, according to the following scheme:

- First two digits - SB
- Digits 3 and 4 - Pilot boring (soil boring) number
- Digits 5 and 6 - The first sample at each boring (depth 0-2 feet) is "01", the second sample at each boring (depth 2.5-4.5 feet) is "02", etc.
- Digit 7 - T, M, or B, designating top, middle, or bottom of the split-barrel sampler; or C, designating a composite of the entire contents of the split-barrel sampler.

For example, the second soil sample collected, from the middle of the split-barrel, at pilot boring SB-01 will be identified as SB-01-02M.

3.6.3 Soil Sampling: Procedure, Equipment, and Frequency

3.6.3.1 Geologic Analytical Samples

Soil samples will be collected for description and stratigraphic interpretation. The samples will be collected using a split-barrel sampler in accordance with ASTM Designation D 1586, Standard Method for Penetration Test and Split-Barrel Sampling of Soils. A copy of ASTM Designation D 1586 is included in Appendix D. The pilot borings will be sampled at 2-1/2 foot intervals. A geologist will examine and log the samples in accordance with ASTM Designation D 2488, Standard Practice for Description and Identification of Soils (Visual - Manual Procedure).

3.6.3.2 Quality Analytical Samples

If visibly contaminated soils are encountered, soil samples from the pilot borings will be collected for laboratory analysis. If headspace screening indicates that the sample contains elevated concentrations of VOCs then a sample from the next interval will be collected for laboratory analysis. Samples would be collected by driving a split-barrel sampler into the bottom of the boring at designated sampling intervals. The split-barrel samples will be collected in accordance with ASTM Designation D 1586, Standard Method for Penetration Test and Split-Barrel Sampling of Soils. The samples will be removed from the split-barrel sampler by hand unless otherwise stated in the SOP. Sampling procedures and equipment will conform to the SOP for Soil Sample Collection (Attachment 1). Sample Custody will conform to the SOP for Chain-of-Custody (Attachment 2). Transporting samples to the laboratory will conform to the SOP for Sample Transporting (Attachment 3).

3.6.4 Soil Sample Quality Screening and Analyses Methods

3.6.4.1 Field Screening Techniques

Four methods will be used in the field to determine evidence of contamination. The methods include: (1) visual examination; (2) oil sheen test; (4) recording of any product or "unnatural" odor; and (4) headspace organic vapor screening. The field screening techniques will conform to the SOP for Field Screening Techniques (Attachment 4).

3.6.4.2 Laboratory Techniques

Analytical Methods for PAH and VOC Samples. Soil samples chosen for analysis will be analyzed for PAH and VOC compounds. The analytical methods are described in detail in the QAPP.

3.7 MONITORING WELL AND PIEZOMETER INSTALLATION (Subtask I.5)

3.7.1 Monitoring Well and Piezometer Objectives and Placement

The objective of the installation of monitoring wells and piezometers in Phase I is to make a preliminary characterization of groundwater quality and flow directions at the site. Eight monitoring wells and four piezometers will be installed at the WCP site.

Four water table monitoring wells will be placed along the northern, eastern, southeastern, and western boundaries of the site. Four deeper wells will be installed nested with the four water table wells located along the boundaries of the site.

Two of the piezometers will be placed in the northeastern and northwestern corners of the site, respectively. Two additional piezometers will be placed near the center of the site, east of existing wells MW1S and MW1D. The proposed locations of the monitoring wells are shown in Figure 3.5-1.

3.7.2 Monitoring Well and Piezometer Designation

The monitoring wells will be designated by the prefix "MW". The MW (Monitoring Well) will be followed by a number and either the letter S or D. The letter S identifies the well as a water table well. The letter D identifies the well as a deeper well. The wells will be assigned consecutive numbers beginning with well MW3 to correspond to wells placed during previous investigations.

The piezometers will be designated by the prefix "P". The P (Piezometer) will be followed by a number. The piezometers will be assigned consecutive numbers beginning with P101.

3.7.3 Monitoring Well and Piezometer Construction

Where applicable, the monitoring wells and piezometers will be installed in the pilot boring boreholes described in Subsection 3.5. Any additional boreholes will be advanced using 3-1/4 or 6-1/2 inch I.D. hollow-stem auger drilling techniques.

The monitoring wells and piezometers will be constructed in accordance with the Illinois Water Well Construction Code (Chapter I, Subpart 920). Water table monitoring wells will be constructed of 2-inch nominal diameter, 10-foot long, No. 10 slot size, stainless steel screens with threaded stainless steel riser pipe. The well screens will be installed to intersect the water table. The deeper monitoring wells will be constructed of 2-inch nominal diameter, 5-foot long, No. 10 slot size, stainless steel screens with threaded stainless steel riser pipe. The deeper wells will be screened in the interval just above the till at elevations similar to the existing deep monitoring wells.

The riser pipe and screen assembly will extend from the base of the borehole to approximately 2½ feet above the ground surface. Centering guides will be used as needed. All joints will be wrench-tight and all threads will be wrapped with Teflon tape. A removable cap to prevent material from entering the well will be placed over the top of the riser pipe prior to placing the sand pack and grout.

The sand pack material will consist of a uniformly graded, clean sand with at least 90 percent by weight passing the No. 10 U.S. Standard sieve and no more than 10 percent by weight passing the No. 40 U.S. Standard sieve. The sand pack will be installed as needed in the annulus between the screen and riser assembly and the borehole from the base of the borehole to approximately 5 feet above the top of the screen. A bentonite seal will be placed above the sandpack. Neat cement grout will be placed above the bentonite seal in the annulus between the riser and borehole with a tremie pipe. The grout will be placed to a depth of 3 feet below the ground surface.

Concrete will be placed in the upper 3 feet of the annular space between the riser pipe and the borehole and sloped to provide drainage away from the well. A 4-inch steel protective casing with a fitted locking cap will be installed over the riser pipe.

The sandpack, bentonite seal, neat cement grout, and concrete will be used in the construction of the deep monitoring wells. Due to the shallow groundwater elevation at the site, the water table wells and piezometers will be constructed using sandpack, bentonite seal, neat cement grout, and concrete as needed.

The monitoring wells and piezometers will be logged. Well logging will include borehole construction, lithology, and well construction data. A copy of the well log form is included in Appendix E.

3.7.4 Monitoring Well and Piezometer Development

Monitoring Wells. Monitoring wells will be developed by pumping and surging the well. The wells will be alternately surged and pumped until produced water is clear and free of turbidity. Final development will be accomplished by using a submersible or centrifugal pump and overpumping. Pump inlets and other equipment that may come into contact with the well will be constructed of stainless steel and/or teflon. Pumps and other equipment will be equipped with check valves to prevent water from reentering the well.

A stabilization test will be conducted on each new monitoring well after the well appears to be fully developed. A well stabilization record is included in the Field Log Data Sheet included in Appendix F. Well stabilization will conform to the SOP for Well Stabilization (Attachments 5, 5a, and 5b).

A minimum of 10 well volumes may be removed from each well during well development and stabilization. If the well produces clear water, free of turbidity and stabilizes prior to the removal of 10 well volumes, then development will be considered completed at that point. Water generated during development will be disposed of in one of the following ways:

discharged to the ground surface near the sampled well, discharged to a POTW, or containerized and treated on-site.

Piezometers. Piezometers will be developed using air lifting. Development will continue until water produced from the piezometer is clear and free of turbidity. A stabilization test will not be performed during the development of the piezometers.

3.7.5 Survey of Monitoring Wells and Piezometers

The elevations of the top of the casing (TOC) and of the ground level at each existing and newly installed monitoring well and piezometer will be surveyed to establish both a vertical and horizontal location. The vertical elevation will be surveyed relative to Mean Sea Level and accurate to within 0.01 foot. The horizontal locations will be established in relationship to a site grid and accurate to within 1 foot.

3.8 WATER LEVEL MONITORING (Subtask I.5)

3.8.1 Water Level Monitoring Objectives

The objective of water level monitoring is to determine groundwater flow directions and gradients. This information will be used to develop a preliminary model of groundwater flow at the site.

3.8.2 Water Level Monitoring: Locations and Frequency

Groundwater elevations will be measured in the newly installed and existing monitoring wells and piezometers no earlier than 24 hours after the completion of the installation of the new wells and piezometers. Groundwater elevations will be measured on at least three separate occasions prior to submission of the RI/FS Report to EPA. If other nearby, accessible private wells for which reliable well logs are available, are found during the RI, water levels will also be measured in the private wells in order to fully delineate the area-wide groundwater flow regime. Water levels will also be

measured in Waukegan Harbor to correlate surface water and groundwater elevations.

3.8.3 Water Level Monitoring: Procedures and Equipment

Water levels in the monitoring wells will be measured using either a popper or an electric water level indicator. Water levels in the piezometers will be measured using either an electric water level indicator or tape and chalk. Water levels will be measured before sample collection. Water level measurement methods will conform to the SOP for Measuring Water Levels in Wells (Attachment 6). Water level measurements will be recorded on the Water Level Data Sheet (Appendix G).

Water levels in Waukegan Harbor will be measured from a surveyed point along the harbor wall.

3.9 GROUNDWATER QUALITY SAMPLING (Subtask I.6)

3.9.1 Groundwater Quality Sampling Objectives

The objectives of Phase I groundwater quality sampling are to:

- Determine the nature and extent of groundwater contamination at the selected locations along the site perimeter;
- Evaluate spatial distribution of contaminants in the groundwater;
- Collect sufficient data to determine whether or not the site poses a threat to potential downgradient receptors (i.e. surface waters;
- Check for nonmanufactured gas/coking plant and noncreosote contaminants in groundwater; and
- Assist in the preliminary selection of possible remedial alternatives.

To accomplish these objectives, samples will be collected from both newly installed and existing wells. Groundwater samples will be analyzed for volatiles, semivolatiles, PCBs, pesticides, metals, and cyanide.

3.9.2 Groundwater Quality Sample Designation

Groundwater quality samples will be assigned a five or six character identifier, to correspond with the monitoring well location. The first four or five characters will be the well identifier. The final character will correspond to the sequence in which the sample was collected from the well during the sampling event. For example, the first groundwater sample collected from MW3D would be labeled MW3D-1.

The following three types of quality control samples will be collected: masked duplicate samples, field blank samples, and equipment blank samples. Quality control samples will be assigned a two or three digit number, depending on the type of quality control sample. Masked duplicate samples will be marked with an M followed by a number indicating the sequence in which the masked duplicate sample was collected during the sampling event. For example, the second masked duplicate sample collected during a sampling event would be labelled M-2. The field blank samples will be marked with FB followed by a number indicating the sequence in which the field blank sample was collected during the sampling event. For example, the second field blank sample collected during a sampling event would be labelled FB-2. The trip blank samples will be marked with TB, followed by a number indicating the sample cooler to which the trip blank is dedicated.

3.9.3 Groundwater Quality Sampling: Locations and Frequency

Groundwater quality sampling locations will consist of existing and new monitoring wells. These locations are shown on Figure 3.5-1.

One groundwater sampling event is proposed for Phase I. The Phase I sampling event will take place within one month of the completion of the proposed monitoring wells and water quality samples will be collected from all site monitoring wells. These samples will be analyzed for the TCL.

3.9.4 Groundwater Quality Sampling: Procedures and Equipment

3.9.4.1 Monitoring Well Preparation

Information regarding well preparation prior to sampling will be recorded on the Field Log Data Sheet (Appendix F).

Measuring Well Depth. The well depth will be measured after groundwater samples are collected. Wells will be measured for their total depth using a tape or cable with a weighted end. All total well depth measurements must be made and recorded to the nearest 0.5 foot.

Measuring Water Level. Water levels will be measured in accordance with the SOP for Measuring Water Levels in Wells (Attachment 6).

Well Purging. Wells are purged before taking samples in order to remove water that may not be representative of aquifer conditions. Wells will be purged according to the SOP for Well Purging (Attachment 7). Water generated during purging will be disposed of in one of the following ways: discharged to the ground surface near the sampled well, discharged to the POTW, or containerized and treated on-site.

3.9.4.2 Well Stabilization Testing

During and after purging (and after new well installation and development) wells must be allowed to stabilize before taking samples to ensure that the groundwater sample is representative of aquifer conditions.

A well is stabilized when the required amount of water has been purged and the specific conductance, temperature and pH of the groundwater are within acceptable limits for three consecutive samples. These three field measurements constitute a stabilization test. Wells will be stabilized according to the SOP for Well Stabilization (Attachments 5, 5a and 5b). A well stabilization record is included on the Field Log Data Sheet.

3.9.4.3 Sample Collection

Once the water level and well depth measurements have been taken, the well has been purged and allowed to stabilize, the Sampler can begin groundwater sampling. A laboratory-cleaned bailer with a Teflon check valve is attached to a ladder-mounted downrigger by stainless steel or Teflon-coated wire. The bailer is lowered into the top of the water column. When the bailer is filled, it is removed from the well and the water is poured into the appropriate sample container. Groundwater sample collection will conform to the SOP for Groundwater Sample Collection (Attachment 8).

3.9.5. Groundwater Quality Sample Handling and Analyses

3.9.5.1 Sample Handling

Sample custody will conform to the SOP for Chain-of-Custody (Attachment 2). Transporting the samples to the laboratory will conform to the SOP for Sample Transporting (Attachment 3).

3.9.5.2 Analytical Methods

Analytical Methods for Volatile, Semivolatile, PCB and Pesticide Samples. Groundwater samples will be analyzed for volatile, semivolatile, PCB pesticide compounds. The analytical methods are described in detail in the QAPP.

Analytical Methods for Metals and Cyanide Samples. Groundwater samples will be analyzed for metals and cyanide. The analytical methods are described in detail in the QAPP.

3.10 HYDRAULIC CONDUCTIVITY TESTING (Subtask I.5)

3.10.1 Hydraulic Conductivity Testing Objectives

The objective of the Phase I hydraulic conductivity testing, utilizing slug tests, is to estimate the horizontal hydraulic conductivity of the surficial sand.

3.10.2 Hydraulic Conductivity Testing Locations

Slug tests will be conducted in all site monitoring wells.

3.10.3 Hydraulic Conductivity Testing: Equipment and Procedures

The slug tests will be conducted by placing a solid PVC "slug" into the well and recording water level changes with time until the water level reequilibrates. The slug will then be rapidly removed from the well and water level changes will be recorded with time until the water level reequilibrates. The water level changes will be monitored during the test using a sensitive pressure transducer and data logging device (Hermit Model 1000, manufactured by In Situ Corp.) enabling rapid and accurate water level measurements. The pressure transducers, slugs, and drop lines will be cleaned in a solution of tap water and TSP between each well, and rinsed with tap water.

SECTION 4

PHASE II INVESTIGATION ACTIVITIES

This section describes the Phase II (Task II) field activities, summarizes the objectives of each activity, and describes the methods used to gather the necessary data. Phase II activities will include: soil boring installation; soil sampling of soil borings for description and geologic interpretation; soil sampling of soil borings for field screening and laboratory analyses of soil quality; soil sampling of soil borings for geotechnical parameters; monitoring well installation; water level monitoring; water quality sampling and analyses; hydraulic conductivity testing; and surveying for location and elevation of soil borings and monitoring wells. A summary of Phase II sampling activities is presented in Table 4.1-1. The proposed schedule for the Phase II activities is shown in Table 1.1-1.

Details of Phase II sampling locations, parameters, and frequencies will be specified in the Phase I Technical Memorandum. The Phase I Technical Memorandum will include: the number and locations of the soil borings and monitoring wells; the number of soil samples to be collected for field and laboratory analysis; the number of soil samples to be collected for geotechnical parameter analysis; the water level monitoring locations; water quality sampling locations; and hydraulic conductivity testing locations.

This section is organized into the following subsections:

- Soil Boring Installation (Subtask II.2)
- Soil Sampling of Soil Borings (Subtask II.2)
- Monitoring Well Installation (Subtask II.3)
- Water Level Monitoring (Subtask II.3)
- Groundwater Quality Sampling (Subtask II.4)
- Hydraulic Conductivity Testing (Subtask II.3)

A subtask number follows each subsection heading in this FSP. The subtask numbers correspond with the subtask numbers used in the proposed schedule.

4.1 SOIL BORING INSTALLATION (Subtask II.2)

4.1.1 Soil Boring Objectives and Placement

The objectives of the soil borings are to:

- Obtain soil samples for soil description and stratigraphic interpretation to delineate the site stratigraphy;
- Provide geological information that will aid in the design of the proposed monitoring wells;
- Obtain soil samples for laboratory analysis to confirm the horizontal and vertical extent of possible subsurface contamination; and
- To obtain soil samples for analysis of parameters that will be used in the screening of remedial alternatives.

Based on the types and locations of site facilities shown in Figure 2.1-2, it is anticipated that four to eight separate areas may be identified in Phase I for further investigation. During Phase II, the vertical and horizontal extent of soil contamination in each area will be characterized with two to six soil borings, depending upon the Phase I results and the size of the area. The borings will be placed in each identified area according to the following rational:

- One boring placed in the zone identified as highly contaminated based on Phase I results (two borings may be placed for areas of greater extent);

- One boring placed in the zone identified as intermediate in contamination (or at the fringe of contamination) based on Phase I results (two borings may be placed for areas of greater extent); and
- One boring placed outside the limit of contamination identified from Phase I results (no borings may be required for areas surrounded by other investigated zones; two borings may be required for more isolated areas).

Based on the assumptions presented above, it is anticipated that approximately 40 soil borings will be placed during Phase II. If no significant contamination is observed during Phase I, or if conditions are significantly different from those anticipated, the rationale for locating soil borings will be reviewed. The locations of soil borings for Phase II will be proposed in the Phase I Technical Memorandum.

4.1.2 Soil Boring Designation

The soil borings will be designated by the prefix "SB". The SB (Soil Boring) will be followed by a number. For example, the soil borings installed in Phase I will be designated SB-1, SB-2, SB3, etc. The Phase II soil borings will be assigned consecutive numbers in sequence with the borings installed during Phase I.

4.1.3 Soil Boring Construction

The Phase I soil borings will be advanced approximately 3 feet. The Phase II soil borings will generally be advanced to the top of the gray silt and clay till; a depth of approximately 25 to 30 feet below grade. The soil borings will be advanced using the 3-1/4 or 6-1/2 inch inner diameter hollow stem auger drilling technique. Hollow-stem augers have a continuous flight-cutting blade around a hollow metal cylinder. A stem with a plug is ordinarily kept inside the auger barrel to prevent soil from entering. When soil samples are desired, the stem is withdrawn and a sampling tool inserted to the bottom of the borehole. Except when a monitoring well is installed

into the borehole, boreholes will be abandoned with neat cement grout following completion. Boreholes will be grouted from the bottom of the hole to the ground surface using a tremie pipe.

Soil cuttings will be spread on the ground in the vicinity of the boring location. Soil cuttings saturated with oil will be containerized and stored on-site.

All drilling equipment, such as hollow stem auger flights, hollow stem auger plugs and downhole tools will be cleaned before use and between boreholes. The drilling equipment will be steam cleaned at the soil boring location. Equipment will be cleaned using one of three methods: (1) steam cleaning, (2) steam cleaning and scrubbing with brush and detergent, or (3) using solvents. Detergent will be used if steam cleaning does not remove all of the oil sheen from the equipment. Solvents will be used to clean equipment if steam cleaning does not remove all visible coal tar. If solvents are needed to clean the drilling equipment, a decontamination pit will be constructed. The decontamination pit will be designed by Barr Engineering Co. and constructed by the contractor. The decontamination pit design will include a low permeability liner installed in either a soil or concrete pit, and equipped with a rinsate water collection system. The decontamination pit design will be provided to the U.S. EPA prior to the pit's construction. The rinse water would be disposed of by: on-site treatment, discharge to the POTW or another approved disposal facility.

4.1.4 Soil Boring Logging

Each soil boring will be logged by an experienced geologist. Logging will include recording: (1) the final depth of the soil boring; (2) the sampling interval; (3) a description of the soil samples and a stratigraphic interpretation; (4) depths of soil samples collected for laboratory analysis, if any; and (5) depth of groundwater encountered. Copies of the soil boring log forms are included in Appendix C.

A geologist will describe soil samples from each soil boring according to ASTM Designation D 2488, Standard Practice for Description and

Identification of Soils (Visual - Manual Procedure). This method of soil classification is comprehensive, logical, and provides a consistent level of accuracy. A copy of ASTM Designation D 2488 is included in Appendix B. The geologist will make a preliminary stratigraphic interpretation of the soil samples based on published information about the geology of the region and site and on information gathered from each soil boring.

4.1.5 Survey of Soil Borings

The soil borings will be surveyed to establish both vertical and horizontal location. The vertical elevation will be surveyed relative to Mean Sea Level and accurate to within 0.1 foot. The horizontal soil boring locations will be established in relationship to a site grid and accurate to within 1 foot.

4.2 SOIL SAMPLING OF SOIL BORINGS (Subtask II.2)

4.2.1 Soil Sample Collection Objectives

The objectives of the soil boring soil sampling are to:

- Describe and interpret the stratigraphy of the fill, surficial sand unit, and clay till;
- Obtain soil samples for laboratory analysis; and
- Obtain representative samples with which to determine grain size distributions, Atterberg limits, gross heating value and flash point of heavily contaminated soils, porosity, and total organic carbon content, and to determine the vertical permeability of the clay unit.

TCLP analyses will also be conducted on heavily contaminated soils. TCLP analyses will be completed on approximately three samples of contaminated soils. Soil samples collected for laboratory analysis will generally be analyzed for PAHs and BETX. Not all samples will be analyzed

for all parameters; Table 4.1-1 outlines the rationale for sample selection. The Phase I Technical Memorandum will discuss any changes to the list of analytical parameters.

4.2.2 Soil Sample Designation

The soil samples collected from the soil borings will be assigned a 7 digit alpha-numeric identifier, according to the following scheme:

- First two digits - SB
- Digits 3 and 4 - Soil boring number
- Digits 5 and 6 - The first sample at each boring (depth 0-2 feet) is "01", the second sample at each boring (depth 2.5-4.5 feet) is "02", etc.
- Digit 7 - T, M, or B, designating top, middle, or bottom of the split-barrel sampler; or C, designating a composite of the entire contents of the split-barrel sampler.

For example, the second soil sample collected from the top of the split-barrel at soil boring SB-04 will be identified as SB-04-02T.

4.2.3 Soil Sampling: Procedure, Equipment, and Frequency

4.2.3.1 Geologic Analytical Samples

Soil samples will be collected for description and stratigraphic interpretation. The samples will be collected using a split-barrel sampler in accordance with ASTM Designation D 1586, Standard Method for Penetration Test and Split-Barrel Sampling of Soils. A copy of ASTM Designation D 1586 is included in Appendix D. The soil borings will be sampled at 2-1/2 foot intervals. A geologist will examine and log the samples in accordance with ASTM Designation D 2488, Standard Practice for Description and Identification of Soils (Visual - Manual Procedure).

4.2.3.2 Geotechnical Analytical Samples

Samples to be analyzed for permeability will be collected with a Shelby tube sampler in accordance with ASTM Designation D 1587, Standard Practice for Thin-Walled Tube Sampling of Soils. A copy of ASTM Designation D 1587 is included in Appendix H. All other samples will be obtained with a split-barrel sampler in accordance with ASTM Designation D 1586, Standard Method for Penetration Test and Split-Barrel Sampling of Soils.

Selected soil samples will be analyzed for geotechnical parameters as follows:

Grain Size Distribution. Three samples of surficial sand and three samples of clay till will be selected to be representative of the hydrostratigraphic units based on the results of the soil classification and to provide areal representation of the site. Additional samples will be submitted as necessary to characterize variations within the hydrostratigraphic units.

Atterberg Limits. Three samples of the clay till; tests to be completed on splits of the samples submitted for grain size distribution analysis. Samples of the fill will also be tested for Atterberg limits, if appropriate.

Porosity. Three samples of the surficial sand unit and three samples of the clay till, selected to be representative of the hydrostratigraphic units based on results of the soil classification and to provide areal representation of the site.

Total Organic Carbon. Three samples of the clay till unit and three samples of the surficial sand unit selected based on the results of the soil classification to be representative of the units and to provide areal representation of the site.

Vertical Permeability. Three samples of the clay till unit will be selected. The samples will be selected to be representative of the unit and to provide areal representation of the site.

TCLP. Approximately three samples will be collected from potentially contaminated areas.

Gross Heating Value. One sample at each location where a TCLP sample is collected.

Flashpoint. One sample at each location where a TCLP sample is collected.

4.2.3.3 Quality Analytical Samples

Field Soil pH. All samples from all borings.

Laboratory PAH. Because wastes containing PAHs may have been placed at or near the present ground surface elevation, one near-surface soil sample from each soil boring will be selected for laboratory analysis. The specific depth intervals for the near-surface samples will be determined based on Phase I information about site stratigraphy and soil contamination, and on depth specific data needs that may be identified for completing the Risk Assessment. In addition, because coal tar and creosote may migrate as dense, nonaqueous phase liquids, one sample from near the contact between the sand unit and the till will be analyzed for PAHs from each boring. Additional samples from the interval between the near surface sample and the sand/till contact sample will be collected for laboratory analysis as necessary to characterize the vertical extent of contamination. Sample selection will be based on field screening results and stratigraphic controls that may be identified. It is assumed that an average of 3.5 samples from each soil boring will be submitted for laboratory analysis of PAHs.

Phenols. Approximately 20 percent of the soil samples analyzed for PAHs will also be analyzed for phenolic compounds. The data will be used to characterize the subsurface distribution of phenols; a smaller number of samples will be collected than for PAH analyses because: (1) phenols are less likely to govern site remediation due to generally lower toxicity and higher regulatory standards than for carcinogenic PAHs; and (2) phenols are generally more mobile than many of the PAHs and, therefore, will be detected

in the groundwater sampling and analysis program if present in soils at levels of concern. Possible correlations between PAH and phenol concentrations in soil samples will be assessed to aid in data interpretation.

Cyanide and Arsenic. Soil samples from borings located near the thionizer building/sulfur pile will be analyzed for cyanide and arsenic. Additional analysis for these sulfur pile constituents may be performed if Phase I results indicate other areas of cyanide and arsenic contamination.

Corrosivity and Reactivity. Soil samples from borings located near the thionizer building/sulfur pile will be analyzed for corrosivity and reactivity.

Field and Laboratory VOCs (BETX). Soil samples will be screened for total VOCs using a field headspace procedure (as described in Attachment 4). Field screening for VOCs measures the total volatile organics in the headspace above a sample which has been broken up inside a jar to free the VOCs. Beginning at a depth of 2.5 feet, all samples taken from borings will be screened in the field for VOCs. Samples selected for laboratory analysis of PAHs will also be submitted for laboratory analysis of BETX. If the total VOCs measured with the field screening procedure exceeds 100 ppm in a sample apparently not containing PAHs, then the next interval down may be sampled for laboratory analysis of VOCs. This method of alternating samples is used for VOCs to minimize opportunity for volatilization from the sample during the sample collection process.

Other Chemical Constituents of Concern. If the analyses of soil and groundwater samples for a broad range of parameters indicates additional chemical constituents require investigation, such chemicals will be addressed in Phase II. Any such parameter will be identified in the Phase I Technical Memorandum.

Soil samples from the soil borings will be collected for laboratory analysis by driving a split-barrel sampler into the bottom of the boring at designated sampling intervals. The split-barrel samples will be collected in

accordance with ASTM Designation D 1586, Standard Method for Penetration Test and Split-Barrel Sampling of Soils. The sample will be removed from the split-barrel sampler by hand unless otherwise stated in the SOP.

4.2.4 Soil Sample Quality Screening and Analyses Methods

4.2.4.1 Field Techniques

Field Screening Techniques. Four methods will be used in the field to determine evidence of contamination. The methods include: (1) visual examination; (2) oil sheen test; (3) recording of any product or "unnatural" odor; and (4) headspace organic vapor screening. The field screening techniques will conform to the SOP for Field Screening Techniques (Attachment 4).

Field Soil pH. Field pH tests will be performed on all soil samples according to the SOP for Field pH (Attachment 4a).

4.2.4.2 Laboratory Techniques

Analytical Methods for BETX Samples. Soil samples will be analyzed for BETX. The analytical method is described in detail in the QAPP.

Analytical Methods for Semivolatile Samples. Soil samples will be analyzed for semivolatile compounds. The analytical methods are described in detail in the QAPP.

Analytical Methods for Arsenic and Cyanide Samples. Selected soil samples will be analyzed for metals and cyanide. The analytical methods are described in detail in the QAPP.

4.2.5 Soil Sample Geotechnical Analytical Methods

Grain Size Distribution. The samples will be analyzed in accordance with ASTM Designation D 422.

Atterberg Limits. The samples will be analyzed in accordance with ASTM Designation D 4318.

Porosity. The samples will be analyzed in accordance with ASTM Designation D 653.

Total Organic Carbon. The samples will be analyzed in accordance with modified EPA Method 415.1.

Vertical Permeability. The samples will be analyzed in accordance with Method No. 7 from U.S. Army Corps. of Engineers Manual 1110-2-1906, Section VII, pp. 17-22.

TCLP. The samples will be analyzed in accordance with the guidelines in 55 Federal Register 26986; June 29, 1990.

Gross Heating Value. The samples will be analyzed in accordance with ASTM Designation D 240-76.

Flashpoint. The samples will be analyzed in accordance with SW846 Method 1010.

4.3 MONITORING WELL INSTALLATION (Subtask II.3)

4.3.1 Monitoring Well Objectives and Placement

The objective of the installation of monitoring wells in Phase II are to:

- Provide groundwater quality information;
- Complete the characterization of site groundwater flow patterns;
-and
- Provide for pumping and slug test permeability characterization.

The Phase I Technical Memorandum will discuss the number and placement of the monitoring wells.

The Phase II monitoring wells will be placed so that their screens are at approximately the same elevation as the screens of the existing wells (MW1S/1D) and Phase I wells (MW3S through MW6S and MW3D through MW6D). The need for wells screened at different intervals will be evaluated once the results of Phase I and the Phase II soil borings are completed.

4.3.2 Monitoring Well Designation

The monitoring wells will be designated by the prefix "MW". The MW (Monitoring Well) will be followed by a number and either the letter S or D. The letter S identifies the well as a water table well. The letter D identifies the well as a deeper well. The wells will be assigned consecutive numbers beginning with well MW7 to correspond to wells placed during previous investigations.

4.3.3 Monitoring Well Construction

Where applicable, the monitoring wells will be installed in the soil boring boreholes described in Subsection 4.1. Any additional boreholes will be advanced using 6-1/2 inch I.D. hollow-stem auger drilling techniques.

The 2-inch monitoring wells will be constructed as described in Subsection 3.7.

In addition, a 4-inch diameter well will be installed at the site for use as the pumping well during the pump test. The location of this well will be chosen after the completion of Phase I and the Phase II soil borings. The well will be constructed of a 4-inch diameter, 10-foot long, No. 10 slot size stainless steel screen and a 4-inch diameter black steel riser. The well will be installed in the same manner as the 2-inch wells described in Subsection 3.7. The 2-inch and 4-inch monitoring wells will be logged. Well logging will include borehole construction, lithology, and well construction data. A copy of the well log form is included in Appendix E.

4.3.4 Monitoring Well Development

Monitoring wells will be developed by pumping and surging the well. The wells will be alternately surged and pumped until produced water is clear and free of turbidity. Final development will be accomplished by using a submersible or centrifugal pump and over-pumping. Pump inlets and other equipment that may come into contact with the well will be constructed of stainless steel and/or teflon. Pumps and other equipment will be equipped with check valves to prevent water from re-entering the well.

A stabilization test will be conducted on each new monitoring well after the well appears to be fully developed. A well stabilization record form is included in the Field Log Data Sheet (Appendix F). Well stabilization will conform to the SOP for Well Stabilization (Attachments 5, 5a, and 5b).

A minimum of 10 well volumes may be removed from each well during well development and stabilization. If the well produces clean water, free of turbidity and stabilizes prior to the removal of 10 well volumes, then development will be considered complete at that point. Water generated during development will be disposed of in one of three ways: discharged to the ground surface near the pumped well, discharged to a POTW, or containerized and treated on-site.

4.3.5 Survey of Monitoring Wells

The elevations of the top of the casing (TOC) and of the ground level at each newly installed monitoring well will be surveyed to establish both a vertical and horizontal location. The vertical elevation will be surveyed relative to Mean Sea Level and accurate to within 0.01 foot. The horizontal locations will be established in relationship to a site grid and will be accurate to within 1 foot.

4.4 WATER LEVEL MONITORING (Subtask II.3)

4.4.1 Water Level Monitoring Objectives

The objective of water level monitoring program is twofold:

- To obtain discrete measurements, which will be used to determine groundwater flow directions and gradients; and
- To obtain continuous measurements, which will be used to determine the possible short-term effects of off-site pumping on local flow pattern and directions and aid in determining the relationship between water levels, recharge events, and surface water (lake) fluctuations.

4.4.2 Water Level Monitoring: Locations and Frequency

Groundwater elevations will be measured in the newly installed and existing monitoring wells and piezometers no earlier than 24 hours after completion of the installation of the new wells. Groundwater elevations will be measured on at least three separate occasions prior to submission of the RI/FS Report to EPA. If other nearby, accessible private wells are found during the RI, water levels will also be measured in the private wells in order to fully delineate the area-wide groundwater flow regime. Water levels will also be measured in Waukegan Harbor to correlate surface water and groundwater elevations.

4.4.3 Water Level Monitoring: Procedures and Equipment

4.4.3.1 Discrete Measurements

Water levels in the monitoring wells will be measured using either a popper or an electric water level indicator. Water levels in the piezometers will be measured using either an electric water level indicator or tape and chalk. Water level measurement methods will conform to the SOP for Measuring

Water Levels in Wells (Attachment 6). Water level measurements will be recorded on the Water Level Data Sheet (Appendix G).

4.4.3.2 Continuous Measurements

Water levels will be measured continuously in two of the water table monitoring wells and one of the deeper wells for approximately one week. An electronic data logger and a sensitive pressure transducer will be used to record the water level elevation every 10 minutes during the continuous water level measurement period. The pressure transducer will be lowered into the well to the appropriate depth below the water level in the well. The transducer cable will be securely taped to the well exterior using duct tape. The data logger will be stored within a locked equipment box next to the well.

4.5 GROUNDWATER QUALITY SAMPLING (Subtask II.4)

4.5.1 Groundwater Quality Sampling Objectives

The objectives of Phase II groundwater quality sampling are to:

- Determine the nature and extent of groundwater contamination in the vicinity of source areas identified in the soils investigation;
- Evaluate spatial distribution of contaminants in the groundwater,
- Collect sufficient data to determine whether or not the site poses a threat to potential downgradient receptors (i.e. surface waters; and
- Assist in the selection of possible remedial alternatives.

To accomplish these objectives, samples will be collected from both newly installed and existing wells. Groundwater samples will likely be analyzed for PAHs, acid extractables, BETX, BOD/COD, oil and grease, and

total suspended solids. Not all samples will be analyzed for all parameters. Table 4.1-1 outlines the rationale for sample selection.

4.5.2 Groundwater Quality Sample Designation

Groundwater quality samples will be assigned a five or six character identifier, to correspond with the monitoring well location. The first four or five characters will be the well identifier. The last character will indicate the sequence of the sample for that sampling event.

Quality control samples will be assigned a two to three digit number, depending on the type of quality control sample is collected. Masked duplicate samples will be marked with an M, followed by the number of the masked duplicate sample. The first two digits of the field blank samples will be FB, followed by the number of the field blank sample.

4.5.3 Groundwater Quality Sampling: Locations and Frequency

Groundwater quality sampling locations will consist of existing and new monitoring wells. Two groundwater sampling events are proposed for Phase II. The first sampling event will take place within one month of the completion of proposed monitoring wells. During the first sampling event, water quality samples will be collected from each monitoring well installed during Phase II. A second sampling event will be scheduled at least one month after the first. During the second sampling event, samples will be collected from all site monitoring wells to provide one site-wide set of contemporaneous quality data.

4.5.4 Groundwater Quality Sampling: Procedures and Equipment

4.5.4.1 Monitoring Well Preparation

Information regarding well preparation prior to sampling will be recorded on the Field Log Data Sheet (Appendix F).

Measuring Well Depth. The well depth will be measured after groundwater samples are collected. Wells will be measured for their total depth using a tape or cable with a weighted end. All total well depth measurements must be made and recorded to the nearest 0.5 foot.

Measuring Water Level. Water levels will be measured in accordance with the SOP for Measuring Water Levels in Wells (Attachment 6).

Well Purging. Wells are purged before taking samples in order to remove water that may not be representative of aquifer conditions. Wells will be purged according to the SOP for Well Purging (Attachment 7). Water generated during purging will be disposed of in one of the following ways: discharged to the ground surface near the well, discharged to the POTW, or containerized and treated on-site.

4.5.4.2 Well Stabilization Testing

During and after purging (and after new well installation and development) wells will be allowed to stabilize before taking samples to ensure that the groundwater sample is representative of aquifer conditions.

A well is stabilized when the required amount of water has been purged and the specific conductance, temperature and pH of the groundwater are within acceptable limits for three consecutive samples. These three field measurements constitute a stabilization test. Wells will be stabilized according to the SOP for Well Stabilization (Attachments 5, 5a, and 5b). A well stabilization record is included on the Field Log Data Sheet.

4.5.4.3 Sample Collection

Once the water level and well depth measurements have been taken, the well has been purged and allowed to stabilize, the Sampler can begin groundwater sampling. A laboratory-cleaned bailer with a Teflon check valve is attached to a ladder and downrigger by stainless steel or Teflon-coated wire. The bailer is lowered into the top of the water column. When the bailer is filled, it is removed from the well and the water is poured into

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the appropriate sample container. Groundwater sample collection will conform to the SOP for Groundwater Sample Collection (Attachment 8).

4.5.5. Groundwater Quality Sample Handling and Analyses

4.5.5.1 Sample Handling

Sample custody will conform to the SOP for Chain-of-Custody (Attachment 2). Transporting the samples to the laboratory will conform to the SOP for Sample Transporting (Attachment 3).

4.5.5.2 Analytical Methods

Analytical Methods for PAHs, BETX, and Acid Extractables Samples. Groundwater samples will be analyzed for PAHs, BETX, and acid extractables. The analytical methods are described in detail in the QAPP.

Analytical Methods for BOD/COD Samples. Groundwater samples will be analyzed for BOD/COD. The analytical methods are described in detail in the QAPP.

Analytical Methods for Oil and Grease Samples. Groundwater samples will be analyzed for oil and grease. The analytical methods are described in detail in the QAPP.

Analytical Methods for Total Suspended Solids. Groundwater samples will be analyzed for TSS. The analytical methods are described in detail in the QAPP.

4.6 HYDRAULIC CONDUCTIVITY TESTING (Subtask II.3)

4.6.1 Hydraulic Conductivity Testing Objectives

The objectives of the Phase II hydraulic conductivity testing include:

- To determine the horizontal hydraulic conductivity of the surficial sand unit, utilizing slug tests;
- To determine the vertical permeability of the till unit, utilizing a modified triaxial permeability test; and
- To estimate the hydraulic conductivity and storage coefficient of the surficial sand unit, utilizing a pumping test.

4.6.2 Hydraulic Conductivity Testing Locations

4.6.2.1 Slug Tests

Slug tests will be conducted in all of the monitoring wells located on-site with the exception of monitoring wells where slug tests were performed during Phase I.

4.6.2.2 Modified Triaxial Permeability Test

A modified triaxial permeability test will be conducted on at least three samples of the upper portion of the clay till unit. The samples will be selected to be representative of the unit and to give areal distribution across the site.

4.6.2.3 24-Hour Pumping Test

A 24-hour pumping test will be conducted in the 4-inch diameter monitoring well. During the pumping test, continuous water level measurements will be taken in at least two water table monitoring wells and at least two deeper monitoring wells. Discrete water levels will be measured in other on-site wells. The Phase I Technical Memorandum will discuss which monitoring wells will be used for continuous and discrete water level measurement. The discrete and continuous water level measurements will be conducted using the methods described in Subsection 4.4.

4.6.3 Hydraulic Conductivity Testing: Equipment and Procedures

4.6.3.1 Slug Tests

The slug tests will be conducted as described in Subsection 3.10.

4.6.3.2 Modified Triaxial Permeability Test

The triaxial permeability test involves placing an undisturbed soil sample under a confining pressure to represent natural conditions. The test is then run using standard falling head permeability test procedures for fine-grained soils.

4.6.3.3 24-Hour Pumping Test

During the pumping test, the 4-inch diameter well will be pumped using a submersible pump. The pump and associated piping will be set by a subcontractor. The pumping system will incorporate a check valve to prevent discharge water from reentering the well. Disposal practices for the pumped water will be proposed following review of Phase I groundwater quality data. Flow rates will be measured using a rotating diaphragm type flow meter equipped with a totalizing digital readout. Both discrete and continuous water level measurements will be measured at various on-site monitoring wells. The Phase I Technical Memorandum will discuss the locations of the monitoring wells that will be used for discrete and continuous measurement.

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Tables

TABLE 1.1-1
ESTIMATED DURATION OF PROJECT TASKS

ACTIVITY	START	TASKS	TASK DURATION (WEEKS)	CUMULATIVE DURATION ⁽¹⁾ (WEEKS)
Phase I Field Investigation	Work Plan Approved	Investigation Support	7	7
		Test Trenching	4	9
		Surficial Soil/Background Sampling	4	9
		Monitoring Wells/Soil Borings	4	13
		Groundwater Sampling/Slug Tests	2	15
		Ecological Survey	2	19
		Sample Analysis/Validation	11	19
		Data Evaluation/Modeling	13	21
		Phase I Tech Memo	9	26
		Revised ARARs/PRG Tech Memo	5	27
		EPA Review	4	30
Phase II Field Investigation	Phase I Tech Memo Approved	Investigation Support	9	39
		Soil Borings	5	39
		Monitoring Wells	4	43
		Pumping Test	1	43
		Groundwater Sampling (1)	1	43
		Sample Analysis/Validation (1)	11	50
		Groundwater Sampling (2)	1	50
		Sample Analysis/Validation (2)	4	54
		Data Evaluation	22	60
		Preliminary Characterization Summary	5	60
		EPA Review	2	62

⁽¹⁾Accounts for concurrent tasks.

TABLE 1.1-1 (continued)
ESTIMATED DURATION OF PROJECT TASKS

ACTIVITY	START	TASKS	TASK DURATION (WEEKS)	CUMULATIVE DURATION ⁽¹⁾ (WEEKS)
RI Report/RA Development and Screening	Preliminary Characterization Summary Approved	Prepare Draft RI Report	12	71
		Prepare Tech Memo on Technologies and Screening Process	12	71
		EPA Review	2	73
		Revisions to Draft RI	4	77
		Prepare Screened Alternatives and Proposed ARARS Tech Memo	9	79
		EPA Approval; Risk Assessment	2;68	79
Alternatives Summary and Evaluation/FS Report	EPA Risk Assessment Completed	PRP Review of Risk Assessment	4	79
		EPA Response	4	79
		Prepare Tech Memo on Alternatives Array Summary	5	84
		Prepare Tech Memo on Comparative Analysis of Alternatives	8	92
		Prepare Draft FS Report	10	97
		EPA Review	2	99
		Revisions to Draft FS/ Submittal of Final FS	5	104
PROJECT TOTAL:				104 weeks (24 months)

⁽¹⁾Accounts for concurrent tasks.

**TABLE 1.1-2
ESTIMATED PROJECT SCHEDULE**

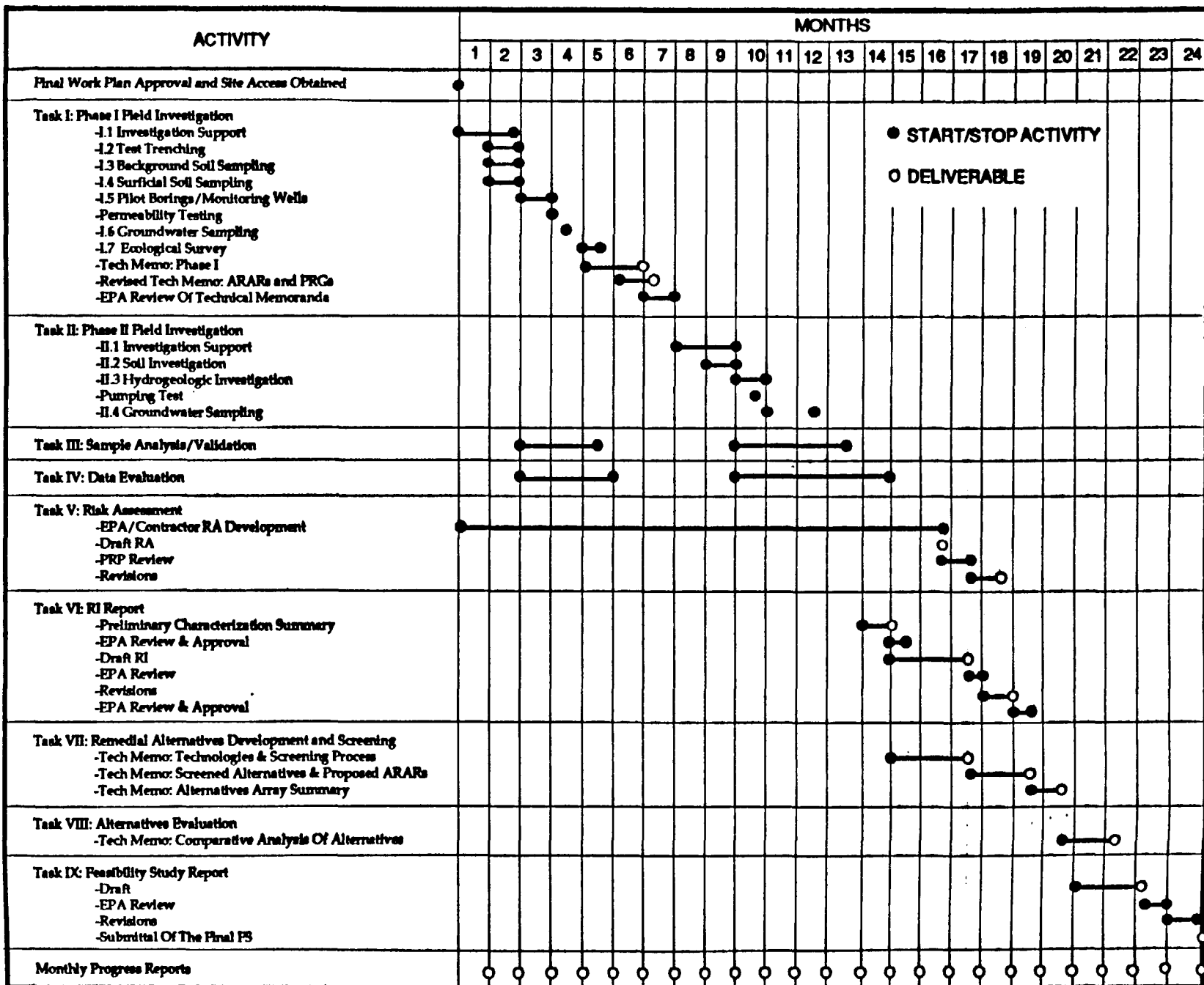


TABLE 3.1-1
PHASE I RI SAMPLING SUMMARY

Sampling Activity	Objective	Estimated No. of Samples	Analytical Parameters	Rationale for Sample Selection
Preliminary Source Area Characterization	Qualitatively identify PAH-contaminated soil for selection of sample locations and Phase II boring locations	140	Field soil classification, visual examination, field oil sheen test, odor observations, field headspace organic vapor screening	One sample to characterize each different-appearing soil encountered; periodic sampling for assessing continuity of similar-appearing soils.
	Characterize nature of key chemical constituents in identified source area wastes/soils	12 of 25	PAHs, VOCs	One sample to characterize each distinct type of visual contamination; assess different levels of visual contamination.
	As above, plus assess levels of phenols and possible correlation with PAHs	5 of 25	PAHs, VOCs, Phenols	Approximately 20% of samples analyzed for PAHs; assess different levels of visual contamination.
	Characterize nature of key chemical constituents associated with thionizer process	3 of 25	PAHs, VOCs, Arsenic, Cyanide	From trenches near Thionizer Building.
	Assess full-range of chemical constituents in identified source area waste/soil	4 of 25	Full-Scan ^m	One from apparent coal-tar waste; one from apparent contamination in new slip area; one from each shallow boring in former pond areas.
	Assess full-range of chemical constituents and leaching characteristics of compacted coal fines layer	1 of 25	Full-Scan ^m , TCLP	From compacted coal fines layer in slip area.
Background Soil Sampling	Assess off-site concentrations of full-range of chemical constituents in soils at surrounding industrial and non-industrial locations	8	Full-Scan ^m	Pre-Determined Locations
Surficial Soil Sampling	Assess nature of on-site soils relative to full-range of chemical constituents	17	Full-Scan ^m	Pre-Determined Locations
Groundwater Sampling	Characterize groundwater quality	10	Full-Scan ^m	New and Pre-Existing Monitoring Wells

^mSemivolatiles, VOCs, Metals, PCBs, Pesticides

TABLE 3.1-2
TARGET ANALYTE LIST AND TARGET COMPOUND LIST
INORGANIC TARGET ANALYTE LIST (TAL)

Analyte	Contract Required Detection Limit ($\mu\text{g/L}$)
Aluminum	200.0
Antimony	60.0
Arsenic	10.0
Barium	200.0
Beryllium	5.0
Cadmium	5.0
Calcium	5,000.0
Chromium	10.0
Cobalt	50.0
Copper	25.0
Iron	100.0
Lead	3.0
Magnesium	5,000.0
Manganese	15.0
Mercury	0.2
Nickel	40.0
Potassium	5,000.0
Selenium	5.0
Silver	10.0
Sodium	5,000.0
Thallium	10.0
Vanadium	50.0
Zinc	20.0
Cyanide	10.0

TABLE 3.1-2 (Cont.)

TARGET COMPOUND LIST (TCL) AND
CONTRACT REQUIRED QUANTITATION LIMITS (CROL)

Volatiles	CAS Number	Quantitation Limits ¹			
		Water $\mu\text{g/L}$	Low Soil $\mu\text{g/Kg}$	Medium Soil $\mu\text{g/Kg}$	On Column (ng)
1. Chloromethane	74-87-3	10	10	1200	(50)
2. Bromomethane	74-83-9	10	10	1200	(50)
3. Vinyl Chloride	75-01-4	10	10	1200	(50)
4. Chloroethane	75-00-3	10	10	1200	(50)
5. Methylene Chloride	75-09-2	10	10	1200	(50)
6. Acetone	67-64-1	10	10	1200	(50)
7. Carbon Disulfide	75-15-0	10	10	1200	(50)
8. 1,1-Dichloroethane	75-35-4	10	10	1200	(50)
9. 1,1-Dichloroethane	75-34-3	10	10	1200	(50)
10. 1,2-Dichloroethane (total)	540-59-0	10	10	1200	(50)
11. Chloroform	67-66-3	10	10	1200	(50)
12. 1,2-Dichloroethane	107-06-2	10	10	1200	(50)
13. 2-Butanone	78-93-3	10	10	1200	(50)
14. 1,1,1-Trichloroethane	71-55-6	10	10	1200	(50)
15. Carbon Tetrachloride	56-23-5	10	10	1200	(50)
16. Bromodichloromethane	75-27-4	10	10	1200	(50)
17. 1,2-Dichloropropane	78-87-5	10	10	1200	(50)
18. cis-1,3-Dichloropropene	10061-01-5	10	10	1200	(50)
19. Trichloroethene	79-01-6	10	10	1200	(50)
20. Dibromochloromethane	124-48-1	10	10	1200	(50)
21. 1,1,2-Trichloropropene	79-00-5	10	10	1200	(50)
22. Benzene	71-43-2	10	10	1200	(50)
23. trans-1,3-Dichloropropene	10061-02-6	10	10	1200	(50)
24. Bromoform	75-25-2	10	10	1200	(50)
25. 4-Methyl-2-pentanone	108-10-1	10	10	1200	(50)
26. 2-Hexanone	591-78-6	10	10	1200	(50)
27. Tetrachloroethene	127-18-4	10	10	1200	(50)
28. Toluene	108-88-3	10	10	1200	(50)
29. 1,1,2,2-Tetrachloroethane	79-34-5	10	10	1200	(50)
30. Chlorobenzene	108-90-7	10	10	1200	(50)
31. Ethyl Benzene	100-41-4	10	10	1200	(50)
32. Styrene	100-42-5	10	10	1200	(50)
33. Xylenes (total)	1330-20-7	10	10	1200	(50)

¹Quantitation limits listed for soil/sediment are based on wet weight. The quantitation limits calculated by the laboratory for soil/sediment, calculated on dry weight basis as required by the contract, will be higher.

PLEASE NOTE: NUMBERS 34 - 125 ARE NOT AVAILABLE ON THIS DOCUMENT. HARD COPIES IN ORIGINAL FILE.

TABLE 3.1-2 (Cont.)

TARGET COMPOUND LIST (TCL) AND
CONTRACT REQUIRED QUANTITATION LIMITS (CRQL)

Volatiles	CAS Number	Quantitation Limits ¹			
		Water	Low Soil	Medium Soil	On Column
		µg/L	µg/Kg	µg/Kg	(ng)
34. Phenol	108-95-2	10	330	10000	(20)
35. bis(2-Chloroethyl) ether	111-44-4	10	330	10000	(20)
36. 2-Chlorophenol	95-57-8	10	330	10000	(20)
37. 1,3-Dichlorobenzene	541-73-1	10	330	10000	(20)
38. 1,4-Dichlorobenzene	106-46-7	10	330	10000	(20)
39. 1,2-Dichlorobenzene	95-50-1	10	330	10000	(20)
40. 2-Methylphenol	95-48-7	10	330	10000	(20)
41. 2,2'-oxybis (1-Chloropropane) ²	108-60-1	10	330	10000	(20)
42. 4-Methylphenol	106-44-5	10	330	10000	(20)
43. N-Nitroso-di-n- dipropylamine	621-64-7	10	330	10000	(20)
44. Hexachloroethane	67-72-1	10	330	10000	(20)
45. Nitrobenzene	98-95-3	10	330	10000	(20)
46. Isophorone	78-59-1	10	330	10000	(20)
47. 2-Nitrophenol	88-75-5	10	330	10000	(20)
48. 4,2-Dimethylphenol	105-67-9	10	330	10000	(20)
49. bis(2-Chloroethoxy) methane	111-91-1	10	330	10000	(20)
50. 2,4-Dichlorophenol	120-83-2	10	330	10000	(20)
51. 1,2,4-Trichlorobenzene	120-82-1	10	330	10000	(20)
52. Naphthalene	91-20-3	10	330	10000	(20)
53. 4-Chloroaniline	106-47-8	10	330	10000	(20)
54. Hexachlorobutadiene	87-68-3	10	330	10000	(20)
55. 4-chloro-3-methylphenol	59-50-7	10	330	10000	(20)
56. 2-Methylnaphthalene	91-57-6	10	330	10000	(20)
57. Hexachlorocyclopentadiene	77-47-4	10	330	10000	(20)
58. 2,4,6-Trichlorophenol	88-06-2	10	330	10000	(20)
59. 2,4,5-Trichlorophenol	95-95-4	50	1700	50000	(100)
60. 2-Chloronaphthalene	91-58-7	10	330	10000	(20)
61. 2-Nitroaniline	88-74-4	50	1700	50000	(100)
62. Dimethylphthalate	131-11-3	10	330	10000	(20)
63. Acenaphthylene	208-96-8	10	330	10000	(20)
64. 2,6-Dinitrotoluene	606-20-2	10	330	10000	(20)
65. 3-Nitroaniline	99-09-2	50	1700	50000	(100)
66. Acenaphthene	83-32-9	10	330	10000	(20)
67. 2,4-Dinitrophenol	51-28-5	50	1700	50000	(100)
68. 4-Nitrophenol	100-02-7	50	1700	50000	(100)

¹Quantitation limits listed for soil/sediment are based on wet weight. The quantitation limits calculated by the laboratory for soil/sediment, calculated on dry weight basis as required by the contract, will be higher.

²Previously known by the name bis(2-Chloroisopropyl) ether.

TABLE 3.1-2 (Cont.)

TARGET COMPOUND LIST (TCL) AND
CONTRACT REQUIRED QUANTITATION LIMITS (CRQL)

Volatiles	CAS Number	Quantitation Limits ¹			
		Water	Low Soil	Medium Soil	On Column
		µg/L	µg/Kg	µg/Kg	(ng)
69. Dibenzofuran	132-64-9	10	330	10000	(20)
70. 2,4-Dinitrotoluene	121-14-2	10	330	10000	(20)
71. Diethylphthalate	84-66-2	10	330	10000	(20)
72. 4-Chlorophenyl-phenyl ether	7005-72-3	10	330	10000	(20)
73. Fluorene	86-73-7	10	330	10000	(20)
74. 4-Nitroaniline	100-01-6	50	1700	50000	(100)
75. 4,6-Dinitro-2-methylphenol	534-52-1	50	1700	50000	(100)
76. N-nitrosodiphenylamine	86-30-6	10	330	10000	(20)
77. 4-Bromophenyl-phenylether	101-55-3	10	330	10000	(20)
78. Hexachlorobenzene	118-74-1	10	330	10000	(20)
79. Pentachlorophenol	87-86-5	50	1700	50000	(100)
80. Phenanthrene	85-01-8	10	330	10000	(20)
81. Anthracene	120-12-7	10	330	10000	(20)
82. Carbazole	86-74-8	10	330	10000	(20)
83. Di-n-butylphthalate	84-74-2	10	330	10000	(20)
84. Fluoranthene	206-44-0	10	330	10000	(20)
85. Pyrene	129-00-0	10	330	10000	(20)
86. Butylbenzylphthalate	85-68-7	10	330	10000	(20)
87. 3,3'-Dichlorobenzidine	91-94-1	10	330	10000	(20)
88. Benzo(a)anthracene	56-55-3	10	330	10000	(20)
89. Chrysene	218-01-9	10	330	10000	(20)
90. bis(2-Ethylhexyl)phthalate	117-81-7	10	330	10000	(20)
91. Di-n-octylphthalate	117-84-0	10	330	10000	(20)
92. Benzo(b)fluoranthene	205-99-2	10	330	10000	(20)
93. Benzo(k)fluoranthene	207-08-9	10	330	10000	(20)
94. Benzo(a)pyrene	50-32-8	10	330	10000	(20)
95. Indeno(1,2,3-cd)pyrene)	193-39-5	10	330	10000	(20)
96. Dibenz(a,h)anthracene	53-70-3	10	330	10000	(20)
97. Benzo(g,h,i)perylene	191-24-2	10	330	10000	(20)

¹Quantitation limits listed for soil/sediment are based on wet weight. The quantitation limits calculated by the laboratory for soil/sediment, calculated on dry weight basis as required by the contract, will be higher.

TABLE 3.1-2 (Cont.)

TARGET COMPOUND LIST (TCL) AND
CONTRACT REQUIRED QUANTITATION LIMITS (CRQL)

Pesticides/Aroclors ³	CAS Number	Quantitation Limits ¹		
		Water µg/L	Soil µg/Kg	On Column (pg)
98. alpha-BHC	319-84-6	0.05	1.7	5
99. beta-BHC	319-85-7	0.05	1.7	5
100. delta-BHC	319-86-8	0.05	1.7	5
101. gamma-BHC (Lindane)	58-89-9	0.05	1.7	5
102. Heptachlor	76-44-8	0.05	1.7	5
103. Aldrin	309-00-2	0.05	1.7	5
104. Heptachlor epoxide	1024-57-3	0.05	1.7	5
105. Endosulfan I	959-98-8	0.05	1.7	5
106. Dieldrin	60-57-1	0.10	3.3	10
107. 4,4'-DDE	72-55-9	0.10	3.3	10
108. Endrin	72-20-8	0.10	3.3	10
109. Endosulfan II	33213-65-9	0.10	3.3	10
110. 4,4'-DDD	72-54-8	0.10	3.3	10
111. Endosulfan sulfate	1031-07-8	0.10	3.3	10
112. 4,4'-DDT	50-29-3	0.10	3.3	10
113. Methoxychlor	72-43-5	0.50	17.0	50
114. Endrin ketone	53494-70-5	0.10	3.3	10
115. Endrin aldehyde	7421-36-3	0.10	3.3	10
116. alpha-Chlordane	5103-71-9	0.05	1.7	5
117. gamma-Chlordane	5103-74-2	0.05	1.7	5
118. Toxaphene	8001-35-2	5.00	170.0	500
119. Aroclor-1016	12674-11-2	1.00	33.0	100
120. Aroclor-1221	11104-28-2	1.00	33.0	100
121. Aroclor-1232	11141-16-5	2.00	67.0	200
122. Aroclor-1242	53469-21-9	1.00	33.0	100
123. Aroclor-1248	12672-29-6	1.00	33.0	100
124. Aroclor-1254	11097-69-1	1.00	33.0	100
125. Aroclor-1260	11096-82-5	1.00	33.0	100

¹Quantitation limits listed for soil/sediment are based on wet weight. The quantitation limits calculated by the laboratory for soil/sediment, calculated on dry weight basis as required by the contract, will be higher.

²There is no differentiation between the preparation of low and medium soil samples in this method for the analysis of Pesticides/Aroclors.

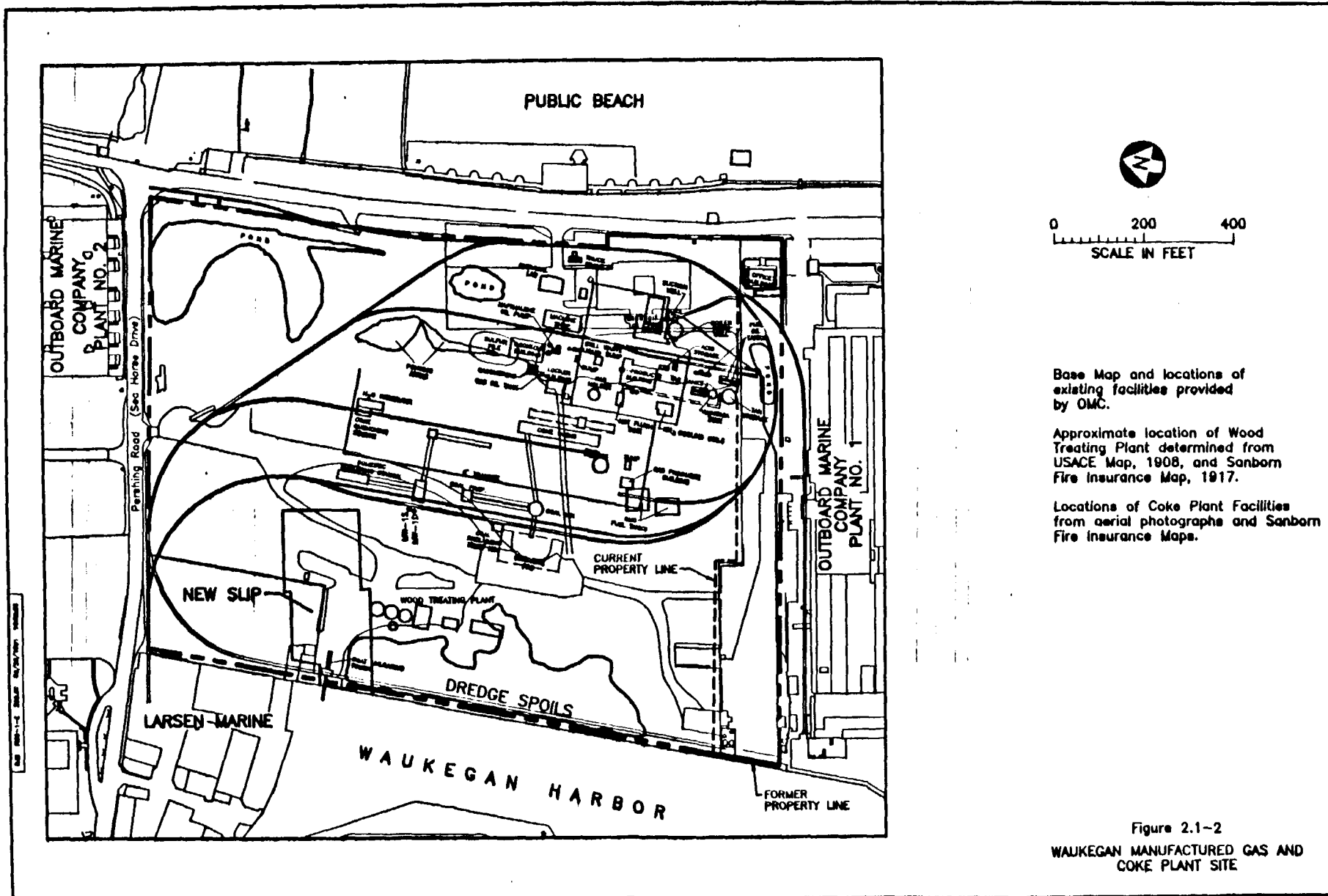
TABLE 4.1-1
PHASE II RI SAMPLING SUMMARY

Sampling Activity	Objective	Estimated No. of Samples	Analytical Parameters	Rationale for Sample Selection
Soils Investigation	Stratigraphic characterization and qualitative identification of PAH-contaminated soil for selection of samples for analyses	480	Field soil classification, visual examination, field oil sheen test, odor observations, field headspace organic vapor screening, field pH	Split-barrel samples collected from borings at 2½-foot intervals
	Assess vertical and horizontal extent of key chemical constituents	102	PAHs, BETX	One near-surface sample from each boring; one sample from sand/till contact at each boring; additional samples based on visual contamination, stratigraphy
	As above, plus assess levels of phenols and possible correlation with PAHs	28	PAHs, BETX, Phenols	Approximately 20% of samples analyzed for PAHs; assess different levels of visual contamination
	Assess vertical and horizontal extent of key chemical constituents and characteristics associated with thionizer process	10	PAHs, BETX, Arsenic, Cyanide, Corrosivity, Reactivity	From borings near Thionizer Building/Sulfur Pile
	Determine basic soil characteristic data	6	Grain size distribution, porosity	3 samples from till, 3 from sand to provide areally representative samples
	Determine basic soil characteristic data	3	Atterberg Limits	1 sample of till from each of 3 borings to provide areally representative samples
	Assess adsorptive nature of sand and till units	6	Total organic carbon	3 samples from till, 3 from sand to provide areally representative samples
	Assess vertical permeability of till	3	Vertical permeability	1 sample from each of 3 borings to provide areally representative samples
	Assess potential treatability alternatives	3	TCLP, gross heating value, flashpoint	3 samples from different areas of soils identified as containing coal tar

TABLE 4.1-1 (continued)

Sampling Activity	Objective	Estimated No. of Samples	Analytical Parameters	Rationale for Sample Selection
Groundwater Sampling	Refine groundwater quality characterization	22	PAHs, BETX, Phenols	1st Round from Phase II monitoring wells; 2nd Round from all monitoring wells; selected samples for low-level PAH analysis based on Phase I results.
	Assess potential treatability alternatives	6	BOD/COD, oil & grease, total suspended solids	1 sample from each well showing relatively high chemical constituent concentrations.

Figures



Base Map and locations of existing facilities provided by OMC.

Approximate location of Wood Treating Plant determined from USACE Map, 1908, and Sanborn Fire Insurance Map, 1917.

Locations of Coke Plant Facilities from aerial photographs and Sanborn Fire Insurance Maps.

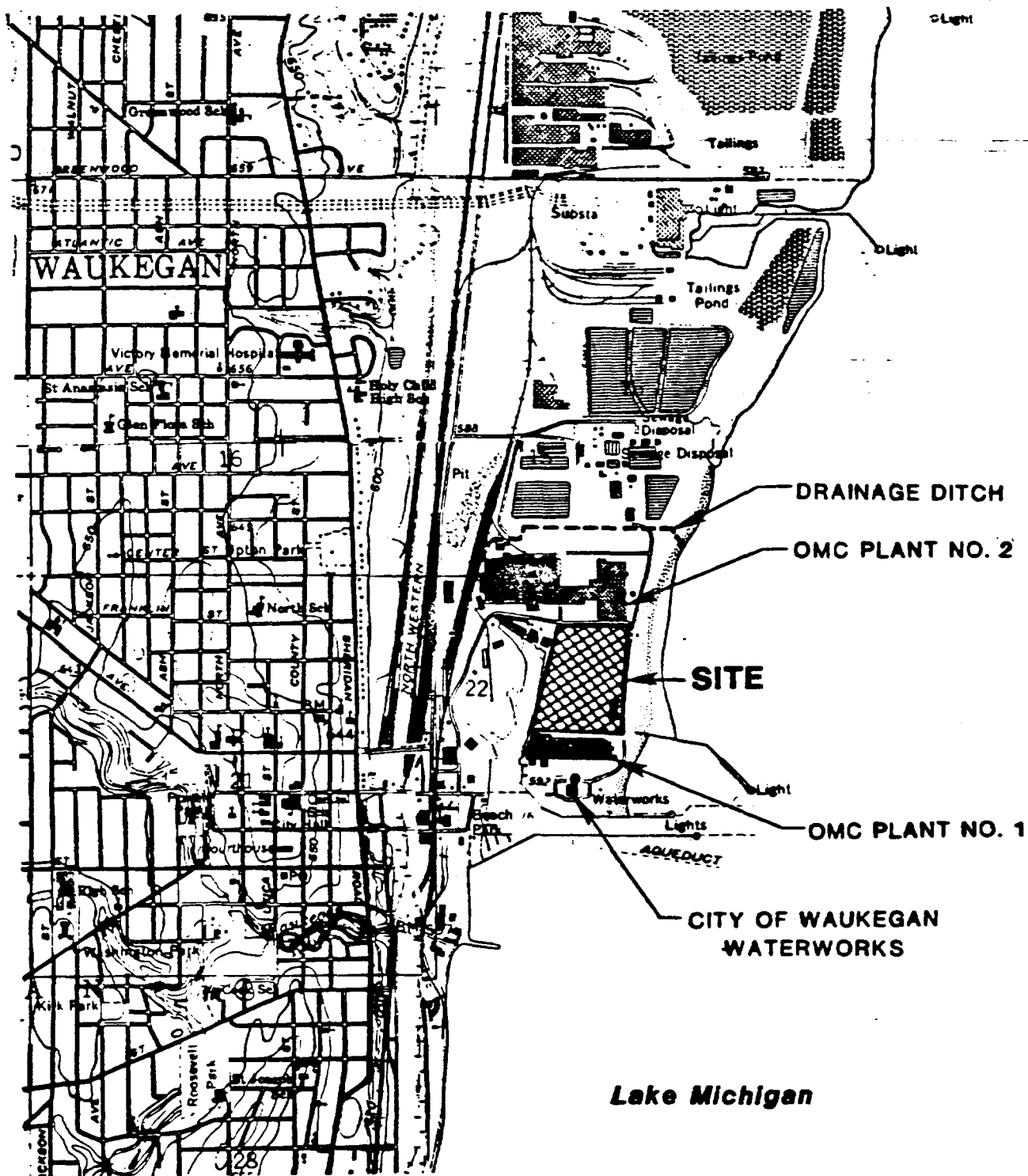
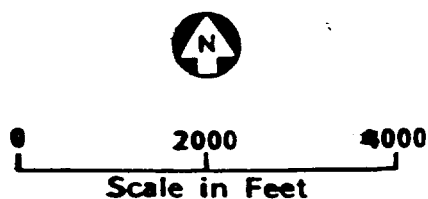
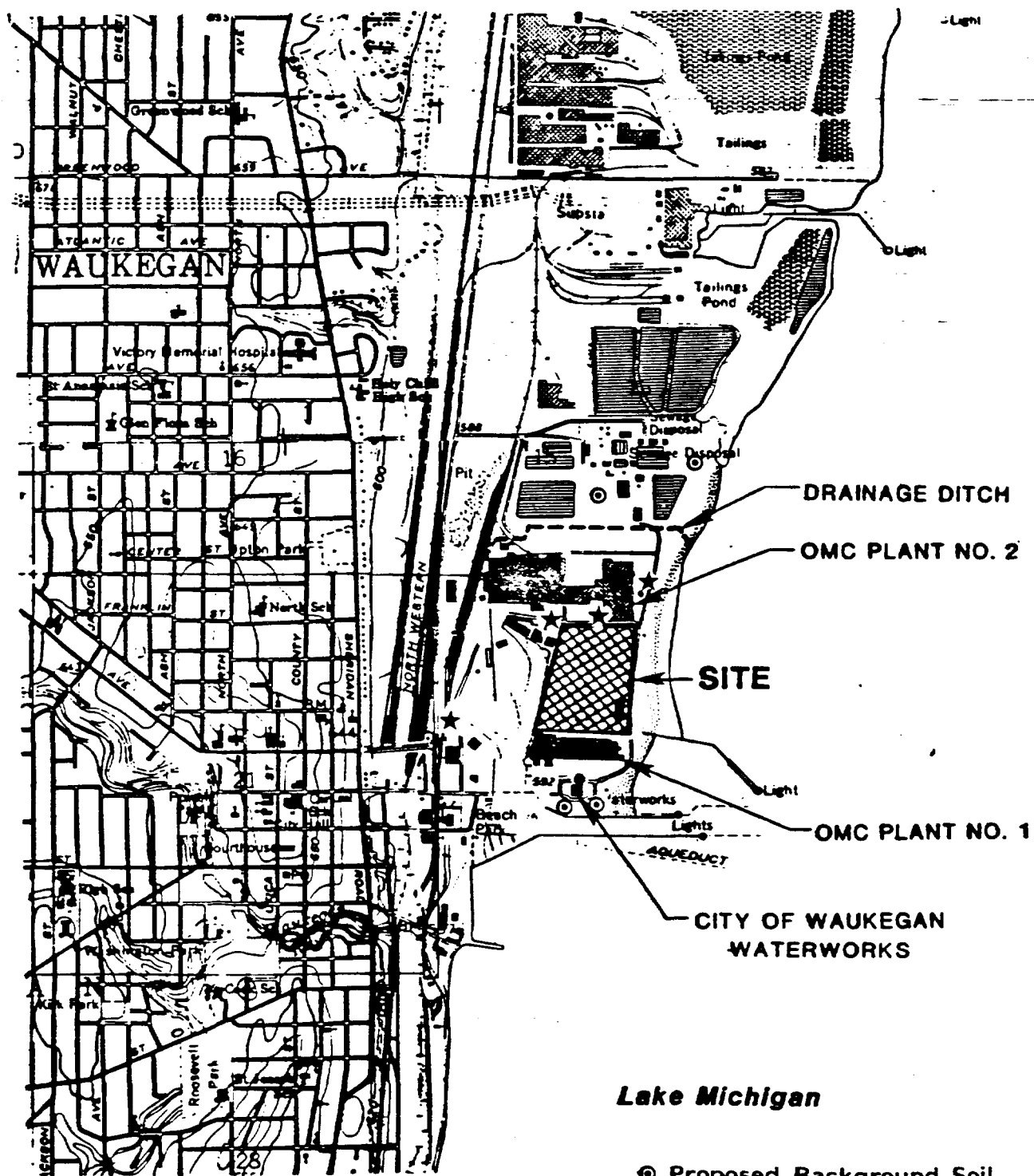


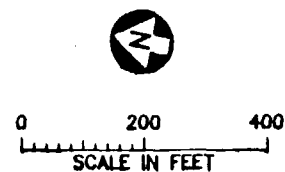
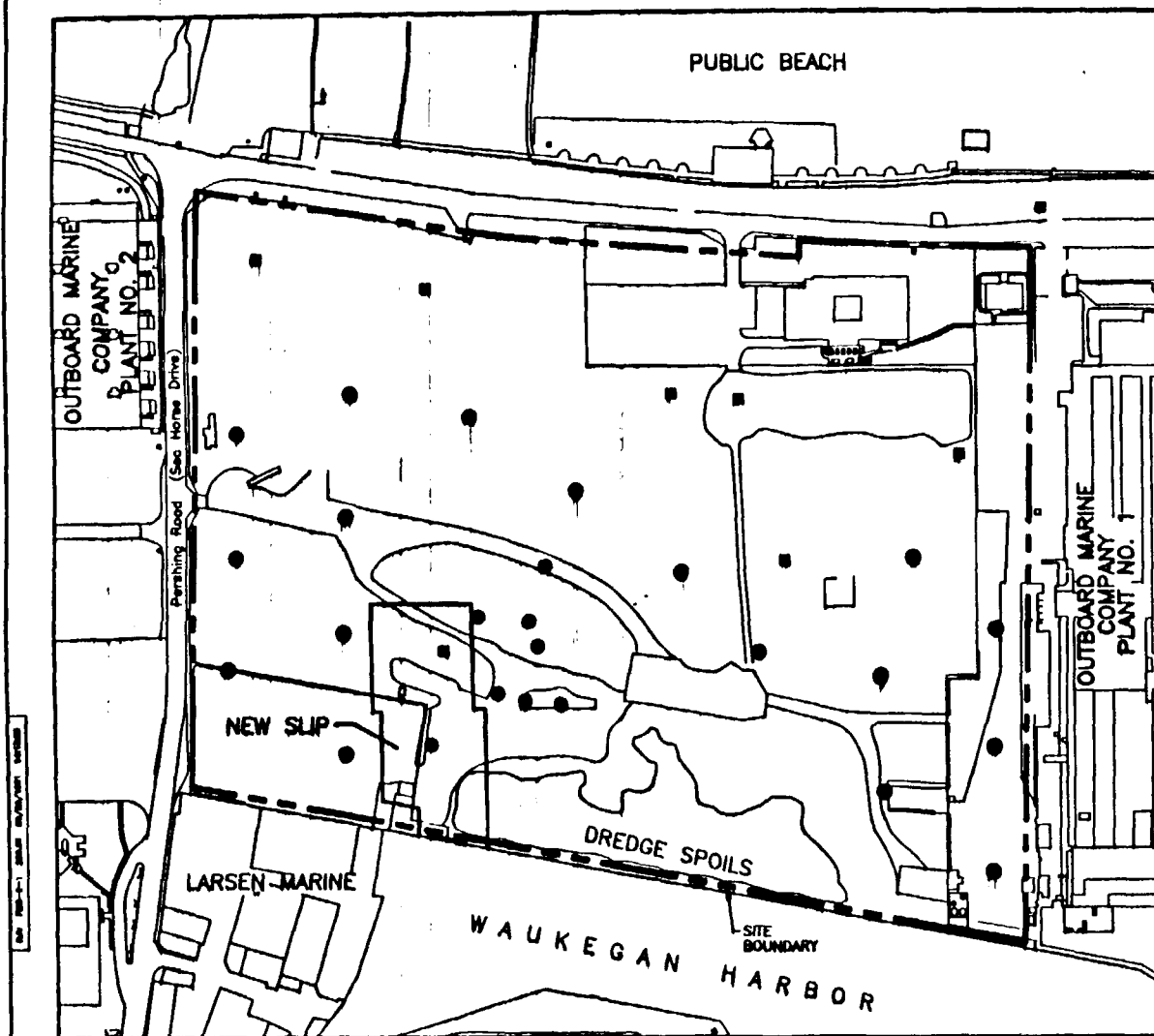
Figure 2.1-1
Site Location Map



Lake Michigan

- ⊙ Proposed Background Soil Sampling Location (Vicinity of Assumed Non-Industrial Operations)
- ★ Proposed Background Soil Sampling Location (Vicinity of Known Industrial Operations)

Figure 3.1-1
PROPOSED BACKGROUND
SOIL SAMPLING LOCATIONS



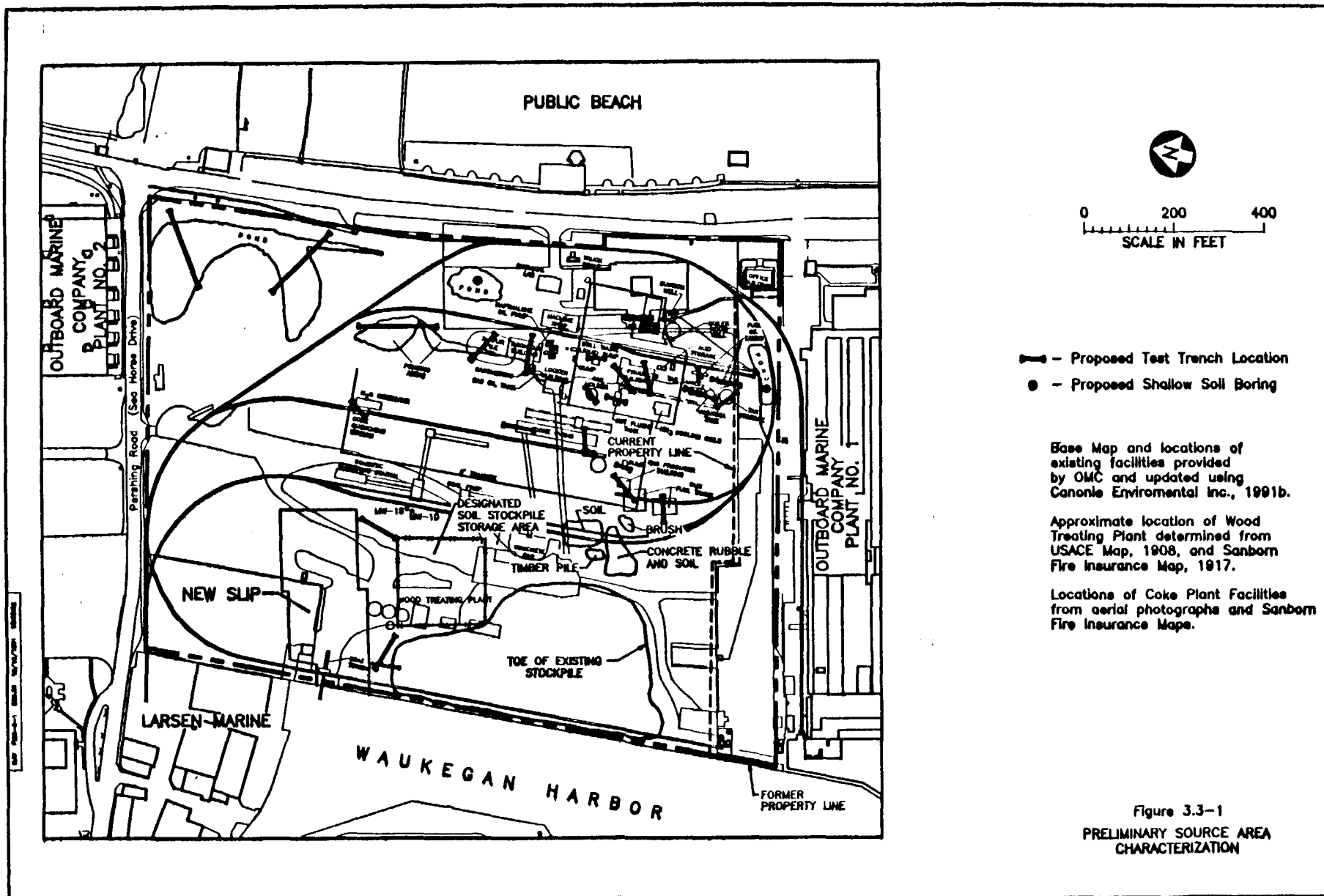
- - IEPA Soil Boring
- - Canonic/EPA Split Sample
- - Proposed Soil Sample Location

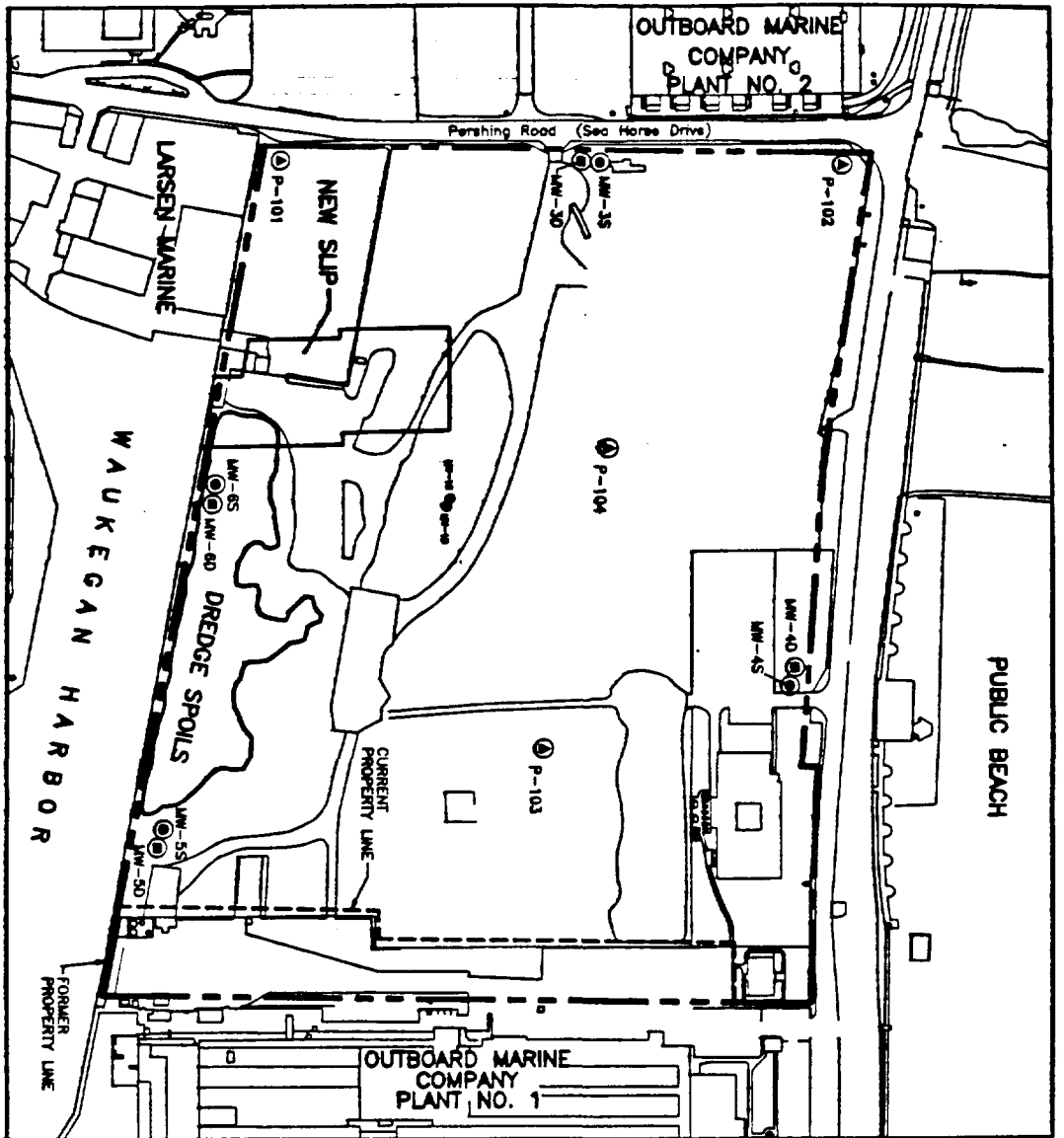
Base Map and locations of existing facilities provided by OMC.

Approximate location of Wood Treating Plant determined from USACE Map, 1908, and Sanborn Fire Insurance Map, 1917.

Locations of Coke Plant Facilities from aerial photographs and Sanborn Fire Insurance Maps.

Figure 3.2-1
PROPOSED
SURFICIAL SOIL SAMPLING
LOCATIONS





- MW-55 (●) - Proposed Water Table Monitoring Well
- MW-50 (●) - Proposed Pilot Boring/Deep Monitoring Well
- P-101 (⊙) - Proposed Piezometer
- MW-15 (●) - Existing Monitoring Well

Figure 3.5-1
PROPOSED
PILOT BORING, MONITORING WELL,
AND PIEZOMETER LOCATIONS

Attachments

Attachment 1

SOP for Soil Sample Collection

ATTACHMENT 1

STANDARD OPERATING PROCEDURE
FOR
SOIL SAMPLE COLLECTION

A variety of samplers (split-barrel, split-barrel with brass liners, backhoe, or shovel) will be used to retrieve soil from sampling locations. Depending on the analysis to be conducted on the soil sample, the soil sample will either be sealed within the sampler (e.g., collecting volatile samples) or the soil sample will be transferred to laboratory-supplied containers. The equipment required to transfer the soil from the sampler to the laboratory-supplied sample containers includes: stainless steel spoons or scoops and the appropriate personal protective equipment necessary for collection and handling of soil samples as described in the Health and Safety Plan.

All soil sampling equipment will be carefully cleaned before and during soil sampling. All sampling tools including split-barrel stainless steel spoons and scoops will be cleaned before use and between samples in the following manner: (1) clean with tap water and TSP, using a brush if necessary to remove particulate matter and films, or (2) rinse thoroughly with tap water. Brass liners will be supplied by the laboratory and transported to the site wrapped in aluminum foil. To prevent sample cross-contamination, the sampler will discard the outer pair of sample gloves and put on a new pair between each sample event.

Collecting Volatile Samples. Soil samples collected for volatile analysis will be retrieved from the sampling location with one of the following: drilling rig equipped with a split-barrel sampler with brass liners, a backhoe, or a hand-auger and a split-barrel rod sampling assembly. The sample collection methods are consistent with IEPA procedures.

The following procedure applies to soil samples retrieved with a drilling rig equipped with a split-barrel sampler with brass liners:

1. Open the split-barrel sampler.
2. Remove one of the two 6-inch long brass liners that are within the split-barrel. If sample recovery has not fully filled both brass liners, remove the fullest of the two liners.
3. Add additional soil to both ends of the brass liner, if necessary, to eliminate headspace.
4. Cover both ends of the brass liner with two sheets of aluminum foil. Cover the aluminum foil with a plastic cap.
5. Cool the sample to approximately 4°C immediately after collection.

The following procedure applies to soil samples retrieved with a backhoe:

1. Remove the aluminum foil from one brass liner.
2. Scrape off the outer few inches of soil in the backhoe bucket to expose a fresh surface.
3. Immediately push the brass liner into the soil in the bucket. Fill the brass liner entirely with soil.
4. Add additional soil to both ends of the brass liner, if necessary, to eliminate headspace.
5. Cover both ends of the brass liner with two sheets of aluminum foil. Seal the ends by covering the aluminum foil with a plastic cap.
6. Cool the sample to approximately 4°C immediately after collection.

The following procedure applies to the collection of hand-augered soil samples:

1. Auger to the desired sampling interval.
2. Remove the aluminum foil from two of the brass liners. Place the liners into a split-barrel sampler equipped with a sand trap.
3. Screw the split-barrel sampler to the rod.
4. Place the sampling assembly into the hand-augered hole.
5. Pound the rod the length of the sampling interval using a post setter.
6. Remove the sampling assembly from the hole and unscrew the split-barrel sampler from the rod.
7. Open the split-barrel sampler and remove one of the brass liners. If sample recover has not fully filled both brass liners, remove the fullest of the two liners.
8. Add additional soil to both ends of the brass liner, if necessary, to eliminate head space.
9. Cover both ends of the brass liner with two sheets of aluminum foil. Seal the ends by covering the aluminum foil with a plastic cap.
10. Cool the sample to approximately 4°C immediately after collection.

If the hand-auger and split-barrel with rod sampling method does not result in an adequate amount of soil sample to fill one brass liner, then the following method will be used:

1. Auger to the top of the desired sampling interval.
2. Remove the auger from the borehole and wipe off the auger flights.

3. Replace the auger and drill the length of the sampling interval.
4. Remove the auger from the borehole.
5. Using a stainless steel spoon, quickly scrape the soil from the auger flights and fill two laboratory-supplied, 2-ounce, wide-mouth glass jars with Teflon-lined caps. Fill the sample containers completely, eliminating any headspace.
6. Cool the sample to approximately 4°C immediately after collection.

Collecting Semivolatile, PCB, and Pesticide Samples.

1. The semivolatile, PCB, and pesticide soil samples will each be collected in one laboratory-supplied, 8-ounce, wide-mouth glass jar with a Teflon-lined cap.
2. The sample container will be filled to three-quarters full using a stainless steel spoon or scoop.
3. Cool the sample to approximately 4°C immediately after collection.

Collecting Metals and Cyanide Samples.

1. The metals and cyanide soil samples will be collected in one laboratory-supplied, 8-ounce, wide-mouth glass jar.
2. The sample containers will be filled to three-quarters full using a stainless steel spoon or scoop.
3. Cool the sample to approximately 4°C immediately after collection.

Collecting TCLP Samples.

1. The TCLP soil samples will be collected in two laboratory-supplied, one-quart glass jars.
2. The sample containers will be filled full using a stainless steel spoon or scoop.
3. Cool the sample to approximately 4°C immediately after collection.

Collecting Gross Heating Value Samples.

1. The gross heating value soil samples will be collected in one laboratory-supplied pint size wide mouth glass jar.
2. The sample container will be filled full using a stainless steel spoon or scoop.
3. Cool the sample to approximately 4°C immediately after collection.

Collecting Flashpoint Samples.

1. The flashpoint soil samples will be collected in one laboratory-supplied pint-size wide mouth glass jar.
2. The sample container will be filled full using a stainless steel spoon or scoop.
3. Cool the sample to approximately 4°C immediately after collection.

Sample Storage. Immediately after samples are collected, they will be put into a cooler containing ice or ice packs. Samples will be kept cold (approximately 4°C) until receipt at the laboratory, where they are to be stored in a refrigerated area. All samples will be kept secured to prevent tampering. The coolers will be sealed with signed and dated tamper-proof

tape. If sample coolers are left in a vehicle or field office for temporary storage, the area will be locked and secured.

Attachment 2

SOP for Chain-of-Custody

ATTACHMENT 2
STANDARD OPERATING PROCEDURE
FOR
CHAIN-OF-CUSTODY

The Chain-of-Custody procedures will ensure that the samples are recorded and tracked from the field to the laboratory. The following procedure applies to all samples collected:

1. Prior to the collection of the sample, label the sample bottle with the information appropriate to that sampling location (e.g., date, well number, sampler's name, etc.).
2. Collect the sample in accordance with the appropriate SOP.
3. If a groundwater sample is collected, record the type of sample(s) collected and the time they were collected on the Field Log Data Sheet. If a soil sample is collected, record the sampling interval and type of sample collected on the appropriate log form (e.g., soil boring log, test trench log, etc.).
4. Assure the integrity of each sample container by either keeping the container in physical possession, keeping the container in view at all times, or storing the container in a secured place.
5. At the end of the sampling event, fill out the Chain-of-Custody form, using the Field Log Data Sheets and verifying the information with the sample containers in the cooler(s). The following information is included on the Chain-of-Custody form:
 - Project number
 - Sample identification
 - Date and time of collection
 - Container type and number
 - Whether the sample is a grab, composite, or blank

- Project manager
- Project contact
- Laboratory
- Analysis required
- Signature of sampler
- Signature of transferee
- Date and time of transfer
- Method of transport

6. Seal the cooler with signed and dated tamper-proof tape.
7. Transport the cooler to the laboratory.

Attachment 3

SOP for Sample Transporting

ATTACHMENT 3
STANDARD OPERATING PROCEDURE
FOR
SAMPLE TRANSPORTING

Prior to the collection of samples, the holding times for the specific analysis will be reviewed. Samples will arrive at the laboratory in time to allow the analysis to be completed. Samples will be sent to the laboratory by overnight delivery within 24 hours of sampling.

Before shipping by air (e.g., by overnight carrier), samples collected during field investigations must be classified by the Project Manager as environmental samples. In general, environmental samples include drinking water, ambient groundwater and surface water, background/control soils, sediment, and any samples not expected to exhibit the characteristics of United States Department of Transportation (U.S. DOT) hazardous materials.

The shipment of samples designated as environmental samples are not regulated by the U.S. DOT. These samples will be transported in such a manner to preserve their integrity.

Attachment 4 and 4a

SOP for Field Techniques

ATTACHMENT 4
STANDARD OPERATING PROCEDURE
FOR
FIELD SCREENING TECHNIQUES
FOR
SOILS CONTAINING COAL TAR

The field screening techniques for soils containing coal tar are as follows: (1) Visual Examination; (2) Oil Sheen; (3) Odor; and (4) Headspace Organic Vapor Screening. The results of these four screening procedures will be used to determine the gross level of PAH contamination of the soil sample.

Visual Examination. A visual examination of the soil sample will include noting any discoloration of the soil or the presence of coal tar.

Oil Sheen Test. The oil sheen test is a method used to immediately determine the approximate magnitude of coal tar contamination in soil by observation of the sample in the field. The test is useful in soils which do not have a high binding capacity with polyaromatic hydrocarbons (PAHs) (i.e., the PAHs are free on the surface of the soil particles and can be released by a stream of water).

The equipment required to conduct the oil sheen test includes: a stainless steel spoon, a squirt bottle filled with tap water, a log book or recording sheet, and the appropriate personal protective equipment necessary for collection and handling of soil samples as described in the Health and Safety Plan. Decontamination of the spoon between test events will consist of scrubbing the surface of the spoon with a solution of trisodium phosphate in water using a brush and then rinsing the spoon with water.

The procedure for conducting the oil sheen test consists of obtaining approximately 50 grams (about 30 cc) of representative soil with the spoon and then directing a stream of water onto the soil in the spoon with the squirt bottle until the soil is saturated and water begins to collect around the soil. The amount of oil sheen present on the water is determined by observation and the results of the test are reported as a magnitude of oil

sheen observed: none, trace, moderate, or heavy. The test results, sample location, and observations of the sample's appearance and odor are recorded in the log book.

The specific soil types at the area of investigation should be accounted for when performing the oil sheen test. The best results are obtained in silts, sands, and/or gravels with low organic content. The results obtained from clayey soils may appear deceptively low. Typical descriptions of each test result are given below.

Oil Sheen Test Result

Description

None

No sheen detected.

Trace

Possible or faint oil sheen observed (May not continue to generate sheen as additional water is added).

Moderate

Definite oil sheen, but "rainbow colors" not distinguishable.

Heavy

Definite oil sheen with "rainbow colors" observed.

Interferences on the test can be caused by any contaminant which will cause an oil sheen on water. The samples will be carefully observed for characteristic appearance or odors which may indicate a possible contaminant other than coal tar.

Odor. Odor will be described as low, moderate, strong, or very strong coal tar odor, or as diesel or petroleum odor. The sampler will note odor only if noticed incidentally while handling the soil sample. The sampler will not place themselves at risk.

Headspace Organic Vapor Screening. The headspace organic vapor screening method will be used in the field to screen soils for organic vapors. The screening method is intended to be used in conjunction with other "real time" observations which include a description of the odor and appearance of the soil sample and an measure of the oiliness of the soil sample.

The equipment required to conduct headspace organic vapor screening includes: a clean pint or quart-size glass jar with lid, aluminum foil, stainless steel spoon, a log book or recording sheet, and the appropriate personal protective equipment necessary for collection and handling of soil samples as described in the Health and Safety Plan.

The following procedure will be used for conducting headspace organic vapor screening:

1. Soil samples collected from a split-barrel sampler will be collected immediately after opening the split-barrel. If the sample is collected from an excavation wall, soil pile, or backhoe bucket, it will be collected from a freshly exposed surface.
2. Half fill a clean glass jar with the sample to be analyzed using a stainless steel spoon. Quickly cover the open top of the jar lid on tightly to seal the jar.
3. Vigorously shake the jar for 15 seconds.
4. Allow headspace development for 10 minutes. Ambient temperature during headspace development should be recorded. When ambient temperatures are below 32°F, headspace development should be conducted inside a heated vehicle or building.
5. Vigorously shake the jar for an additional 15 seconds.
6. Remove the jar lid to expose the aluminum foil seal. Quickly puncture the foil seal with the sampling probe to a point about one-half of the headspace depth. Exercise care to avoid uptake of water droplets or soil particles.
7. Record the highest meter response as the headspace concentration. The maximum response will likely occur between two to five seconds.

ATTACHMENT 4A
STANDARD OPERATING PROCEDURE
FOR THE
FIELD MEASUREMENT OF SOIL pH

PURPOSE: The purpose is to describe the method by which pH measurements on soil samples will be made and documented in the field.

RESPONSIBILITIES: The soil samplers are responsible for making and documenting the field soil pH measurements.

EQUIPMENT/MATERIALS: Litmus paper
Paper cups (unwaxed)
Wooden tongue depressors
Distilled water

- PROCEDURES:**
1. As soon as possible after sample retrieval, place a tablespoon of soil in a paper cup.
 2. Add enough distilled water to the soil so that the total volume of the soil suspension is one-fourth of the cup.
 3. Stir the suspension several times with the wooden tongue depressor.
 4. Place litmus paper into the suspension.
 5. Wait for color of litmus paper to stabilize as directed by the manufacturer of the litmus paper.
 6. As directed by the manufacturer, compare the color of litmus paper to the color chart on the

litmus paper container and record the pH to the nearest unit.

DOCUMENTATION:

pH values of samples will be written down on the field data sheet for the samples from each boring. The results will be reported as "soil pH measured in water."

Attachments 5, 5a, 5b

SOP for Well Stabilization

ATTACHMENT 5
STANDARD OPERATING PROCEDURE
FOR
WELL STABILIZATION TESTS

Stabilization tests start after three well volumes have been purged from the well and are taken after every well volume purged after that until three consecutive tests are within acceptable limits.

A conductivity meter is used to measure the specific conductance and temperature of the groundwater. A pH meter is used to measure the pH. This equipment is described below.

• Conductivity Meter

Specific conductance is measured in the field using a conductivity meter. The following instrument or its equivalent will be used for analyses in the field: YSI Model 33 specific conductivity meter.

The meter is a portable, battery-powered, transistorized instrument designed to measure conductivity, salinity, and temperature. It uses a probe consisting of a combined plastic conductivity cell and a temperature sensor. Conductivity measurements made by the meter are not temperature compensated; however, a temperature function is provided on the instrument to aid with calculating corrections. Conductivity measurements will be corrected to 25°C.

After each use at the site, the probe must be rinsed with laboratory grade detergent and rinsed with deionized water to remove oily substances or potential contamination.

The temperature of a sample is usually determined using a conductivity meter that is equipped with a temperature function. The YSI Model 33 Conductivity Meter has a temperature function.

• pH Meter

Field measurements of pH are determined using a pH meter. The following instrument or its equivalent will be used for the analysis of pH in the field: Orion Research Model 407A pH meter. This meter is battery powered and can be used for a variety of measurements, including pH and Eh.

After each use at the site, the meter's probe must be rinsed with laboratory-grade detergent and rinsed with deionized water to remove oily substances or potential contamination.

Groundwater samples are collected either from the flowing water or with a bailer (depending on the purge method being used), and filling a plastic bottle. Probes from both meters are placed in the bottle. All parts of the conductivity meter probe must be completely covered with water. Allow the readings to stabilize, then record the specific conductance, temperature, and pH of the sample. After an additional well volume has been purged, another sample is collected and tested. The procedure is repeated until three samples display readings within acceptable limits. These acceptable limits are:

Specific Conductance: Readings from 0 to 500 must be within ± 5 umhos/cm @ 25°C. Readings from 500 to 5,000 must be within ± 50 umhos/cm @ 25°C.

Temperature: Readings must be within $\pm 0.5^\circ\text{C}$.

pH: Readings must be within ± 0.1 units.

It should be noted that groundwater samples for laboratory analysis are never taken from the stabilization test bottles. Samples for laboratory analysis are always taken directly from the flowing purge water or from the bailer. All stabilization test equipment will be cleaned between wells with tap water and TSP and rinsed with tap water.

ATTACHMENT 5a

**STANDARD OPERATING PROCEDURES
FOR THE
CALIBRATION AND OPERATION
OF THE pH METER**

PURPOSE: The purpose is to describe the use of the pH meter, its calibration, documentation, and readings.

RESPONSIBILITIES: The field technicians are responsible for the use, calibration, documentation of pH readings.

EQUIPMENT:	Orion Model 407A/F	Reads pH 0.1 units
	Orion Model SA205	Reads pH 0.1 or 0.01 units
	Orion Model pH60	Reads pH 0.01 units

PROCEDURES: Two-buffer calibration:

1. Turn meter on, let warm up three minutes.
2. Connect pH electrode to meter.
3. Place meter in pH mode.
4. Place electrode into calibration solution #1 (7.00 buffer).
5. Let reading stabilize, adjust reading to 7.00, if necessary.
6. Rinse electrode, place into calibration solution #2 (10.00 buffer).
7. Let reading stabilize, adjust reading to 10.00.
8. Rinse electrode and place into sample.
9. Read pH off of meter to nearest tenth.

Accuracy requirements:

A properly functioning electrode and meter will have a slope of 90 percent to 102 percent. The slope is

checked after calibration using the following procedure:

1. Place meter in slope mode.
2. Read slope.
3. If in range, proceed to take reading; if out of range, these steps are necessary.
4. Check battery, replace or recharge if low.
5. Check pH electrode connection to meter.
6. Clean pH electrode and replace reference solution.
7. Use fresh buffer solutions.
8. Try new probe.
9. Send in meter to be repaired.

Sample analysis:

1. Rinse pH electrode.
2. Place electrode into sample.
3. Wait for pH reading to stabilize (1 to 5 minutes).
4. Read and record pH reading to the nearest tenth unit.
5. Remove electrode from sample and rinse.
6. Store electrode in buffer solution or storage solution between sample measurements.

QUALITY CONTROL:

Accuracy of field measurement of pH will be determined by calibration verifications every five samples collected and at the end of the day. The accuracy will be assessed by performing two measurements on two standard buffer solutions which bracket the pH range of the samples. Each measurement will be within ± 0.1 standard unit of buffer solution or the meter will be recalibrated.

Precision will be assessed through duplicate measurements at a frequency of 10 percent or one per day minimum. If duplicate measurement of pH is not within 0.1 pH units, the pH meter will be recalibrated.

DOCUMENTATION:

The technician will document the calibration and any pertinent information in each meter's log book. Calibration will be done at the start of the sampling day. Calibration verification will be done after every five samples collected and again at the end of the day. pH values of samples will be written down on the field log data sheets for each sample collected.

ATTACHMENT 5b
STANDARD OPERATING PROCEDURES
FOR THE
CALIBRATION AND OPERATION
OF THE
CONDUCTIVITY AND TEMPERATURE METER

PURPOSE: The purpose is to describe the use of the conductivity and temperature meter, its calibration, and documentation and readings.

APPLICABILITY: These procedures apply to finding the conductivity and temperature of a water sample.

DEFINITIONS: Redline: This is a setting on the conductivity and temperature meter to show if the meter is zeroed and to check the battery.

REFERENCE: The Instructions for YSI Model 33 S-C-T Meter, Yellow Springs Instrument Co., Yellow Springs, Ohio.

RESPONSIBILITIES: The Environmental Technicians are responsible for the operation, maintenance, and checking calibration of conductivity and temperature meter.

PROCEDURE: Calibration (Daily Verification)

1. Turn meter to redline.
2. Meter warm up (two to three minutes).
3. The meter needle should then be exactly on the redline (located on the far right of the display screen).

4. Adjust the redline dial accordingly to receive and accurate display.
5. If redline malfunctions change battery.

Calibration of Conductivity (daily)

1. Redline meter.
2. Put probe into conductivity calibration solution (YSI 3167 Conductivity Calibrator, assayed at 0.997 millimho/cm, with a composition of potassium chloride, water, and 0.0002 percent iodine).
3. Check temperature of solution.
4. Check conductivity of solution.
5. Match meter readings with prescribe readings (prescribe readings are found accompanying the solution).
6. Reading should be within 50 umhos/cm of the prescribe reading.
7. If conductivity readings do not match:
 - a. Check probe connection to meter
 - b. Change battery
 - c. Clean probe
 - d. Try different conductivity solution
 - e. Replatinize probe
 - f. Change probe
 - g. Send meter to be fixed

Sample Analysis:

1. Rinse conductivity probe.
2. Select desired mode (temperature or conductivity).

NOTE: The conductivity model, the user must set dial to desired range of measurement (X1, X10, X100 umhos/cm range) according to the sample conductivity.

3. Place probe into sample and move it around in the sample to remove any air bubbles inside the probe.
4. Wait for measurement (temperature or conductivity) to stabilize (about one to five minutes).
5. Read and record conductivity measurement and temperature.

NOTE: Conductivity must be calculated to the standardized 25°F.

DOCUMENTATION: The technicians will document the procedures done in redlining daily and checking of conductivity weekly. This will be written down in the log book for each meter. Any other pertinent information will also be noted in the log book for each meter. The conductivity and temperature readings for each sample will be recorded on the field log data sheets for each sample collected.

Attachment 6

SOP for Measuring Water Levels in Wells

ATTACHMENT 6
STANDARD OPERATING PROCEDURE
FOR
MEASURING WATER LEVELS IN WELLS

For new wells, water level measurements should not be taken until the water table has stabilized -- preferably 24 hours after well installation and/or development. Water levels will be measured before sample collection.

All groundwater level measurements are made and recorded to the nearest 0.01 foot.

To ensure consistent results, all groundwater level measurements are made in reference to an established point on the well casing. Water level measurements are made from the high side of the riser pipe or well casing unless otherwise specified. Measuring the distance from the top of the well to the groundwater surface can be accomplished using a popper, an electric water level indicator, or the tape and chalk method, described below. All water level measuring devices will be cleaned between wells with tap water and TSP and rinsed with tap water.

• Popper

A cup-shaped weight that is hollow on the bottom is attached to a measuring tape and lowered into the well. A "popping" sound is made when the weight strikes the surface of the water. An accurate reading can be determined by lifting and lowering the weight in short strokes and reading the tape when the weight barely strikes the water. Most poppers have a correction factor because of the way they are made. Always check the popper's correction factor and record the corrected water levels.

The "popping" sound cannot be heard in wells where the water level is in the screen. Another water level measuring device should be used in this type of well.

- Electric Water Level Indicator

This instrument consists of a spool of wire, a probe attached to the end, and an indicator. When the probe comes in contact with the water, the circuit is closed and a meter light and/or buzzer attached to the spool signals the contact. AA batteries are normally used for a power source. Always have spare batteries on hand.

- Tape and Chalk

The tape and chalk method is used when neither the popper nor the electric water level indicator method worked. To determine the water level with tape and chalk, cover the first 2 to 3 feet of metal tape with chalk. Lower the tape to the expected depth of the water and note the depth of the tape against the high side of the well casing. After removing the tape from the well, note the highest point on the tape that has been wetted. Subtract that number from the total depth of the tape to determine the depth to water.

Attachment 7

SOP for Well Purging

ATTACHMENT 7
STANDARD OPERATING PROCEDURE
FOR
WELL PURGING

One method of purging is to pump the well until three to five times the volume of standing water in the well is removed. A second method is to pump the well until the groundwater's specific conductance, temperature, and pH stabilize. Normally, a combination of the two methods is used; i.e., specific conductance, temperature and pH are measured at intervals and the volume purged is monitored. If a well is pumped dry, this constitutes an adequate purge and can be sampled following recovery. All well purging equipment will be cleaned between wells with tap water and TSP and rinsed with tap water.

Purging can be done using a bailer, or one of three types of pumps can be used: peristaltic, centrifugal, or submersible.

• Bailer

A bailer is used for wells with an inside diameter less than 4 inches and a depth to groundwater greater than 25 feet. The laboratory-cleaned stainless steel bailer with a Teflon check valve is attached to a downrigger and ladder assembly. Teflon-coated wire and single-strand stainless steel wire are both acceptable for hauling bailers.

• Peristaltic Pump

This pump is used when the water level is within suction lift, i.e., about 25 feet down. It usually is a low volume suction pump with low pumping rates suitable for sampling shallow, small diameter wells.

- Centrifugal Pump

Like the peristaltic pump, the centrifugal pump is used when the water level is within suction lift, i.e., about 25 feet down. It has pumping rates from 1 to 20 gpm and can be used in wells within a diameter of at least 1.75 inches. A stainless steel bailer with a Teflon check valve is attached to the end of the pump hose to prevent water from reentering the well.

- Submersible Pump

This pump is used to collect samples from depths that exceed the suction lift, i.e., below 25 feet. A tripod and winch assembly lowers and raises the pump inside the well, requiring a source of electric power which is usually a generator. Most submersible pumps can be used only on wells with an inside diameter of at least 4 inches.

In general, peristaltic and centrifugal pumps are used for wells with water levels less than 25 feet down. Submersible pumps are used for wells with lower water levels, but the wells must have an inside diameter of at least 4 inches. Bailers are used for wells with water levels below 25 feet and diameters less than 4 inches.

When peristaltic pumps are used, only the intake line is placed into the well. When a centrifugal pump is used, a stainless steel bailer with a Teflon check valve is attached to the end of the hose and lowered into the well. When submersible pumps are used, the pump itself is lowered into the water column, usually using a tripod and winch.

The pump/hose assembly used in purging should be lowered into the top of the standing water column and not deep into the water. This is done so that the purging will "pull" water from the formation into the screened area of the well and up through the casing so that the entire static volume can be removed. If the pump/hose is placed deep into the water column, the water above the pump may not be removed, and the subsequent samples may not be representative of the groundwater.

If well recovery (groundwater reentering the well from the surrounding formation) is at least as fast as the pumping rate, the pump/hose may be left hanging at the initial level until an adequate volume of water is removed. If the pumping rate exceeds the well's recovery rate, the pump will have to be lowered as needed to accommodate the drawdown.

A laboratory-cleaned bailer with a Teflon check valve is attached to a ladder and downrigger by stainless steel or Teflon-coated wire. The bailer assembly is lowered into the top of the water column. When the bailer has filled, it is removed from the well and the water is poured into a bucket marked in quarts for volume measurement.

Measuring Well Pumping Rate. If a flow meter is installed on the well, simply read the meter. If no meter is available, the pumping rate can be determined by using a bucket marked in quarts and a stopwatch to time how long it takes for the bucket to fill with purge water. Be aware that changes in the flow rate will affect the amount of time required to purge the necessary amount of water from the well.

Measuring Purge Volume. The volume of standing water in the well is calculated first to determine the amount of purge water that needs to be removed from the well. The water level must be measured in order to determine the volume of standing water. The volume of standing water in the well is calculated using the following equation:

$$V = (\pi)(r^2)(h)$$

where: V = volume, in cubic feet

$$\pi = 3.14$$

r = radius of the well casing or hole (in feet)

h = height of the column of water in the well (in feet)

Then convert the volume of water standing in the well from cubic feet to gallons by multiplying the volume by 7.48.

Then determine the amount of water that must be purged by multiplying the gallons of standing water in the well by the number of well volumes that are required to be purged.

Attachment 8

SOP for Groundwater Sample Collection

ATTACHMENT 8
STANDARD OPERATING PROCEDURE
FOR
GROUNDWATER SAMPLE COLLECTION

Once the water level and well depth measurements have been taken, the well has been purged and allowed to stabilize, the Sampler can begin groundwater sampling. The following procedure applies to groundwater sample collection:

1. A laboratory-cleaned bailer with a Teflon check valve is attached to a ladder and downrigger by stainless steel or Teflon-coated wire.
2. The bailer is lowered into the top of the water column.
3. When the bailer is filled, it is removed from the well and the water is poured into the appropriate sample container.

Collecting Volatile Samples

1. Samples to be analyzed for volatile organics will be collected in two 40-ml vials with Teflon-lined septum caps and preserved with four drops of hydrochloric acid to reduce the pH to less than 2.

Once each day of a sampling event, a duplicate sample will be collected and field checked to determine the pH of the sample. If the pH is greater than 2, the laboratory will be instructed to reduce the holding time of that day's samples to the 7-day holding period used for unpreserved samples.

2. There should be no headspace present in the vial. If a headspace is noted, the sample will be discarded and a new sample taken.
3. These samples will be cooled to approximately 4°C.

Collecting Semivolatile Samples

1. Samples to be analyzed for semivolatile organics will be collected in a 1-gallon amber glass jar with a Teflon-lined septum cap.
2. These samples will be cooled to approximately 4°C.

Collecting Metals Samples

1. Samples to be analyzed for metals will be collected in a 1-liter polyethylene jar with a polyethylene lined closure.
2. These samples will be preserved in the field with a 50 percent solution of Nitric Acid to reduce the pH of the sample to less than 2.

Collecting COD Samples

1. Samples to be analyzed for COD will be collected in one laboratory-supplied, 8-ounce polyethylene jar with a polyethylene lined closure.
2. The samples will be preserved in the field with sulfuric acid to reduce the pH of the sample to less than 2.
3. The samples will be cooled to approximately 4° C.

Collecting BOD Samples

1. Samples to be analyzed for BOD will be collected in one laboratory-supplied, 1-liter polyethylene jar with a polyethylene lined closure.
2. The samples will be cooled to approximately 4° C.

TABLE A.8-1

SAMPLE CONTAINERS, PRESERVATION AND HOLDING TIMES

Parameter	Container	Preservation	Maximum Holding Time	Minimum Volume
Base/Neutral, Acid Extractables	Glass, Teflon-lined cap	Cool, 4°C	7 days to extraction; 40 days after extraction	2,000 ml
Cyanide	Plastic or glass	Cool, 4°C, NaOH to pH>12, .06 g ascorbic acid	14 days	1/2 gallon
Metals (except Hg)	Plastic or glass	HNO ₃ to pH<2	6 months	500 ml
Mercury	Plastic or glass	HNO ₃ to pH<2	28 days	500 ml
Oil and Grease	Glass	Cool, 4°C, H ₂ SO ₄ to pH<2	28 days	1,500 ml
Total Suspended Solid	Plastic or glass	Cool, 4°C	7 days	200 ml
Pesticides/PCBs	Glass, teflon-lined cap	Cool, 4°C	7 days extraction; 40 days after extraction	2,000 ml
Chemical Oxygen Demand	Plastic or glass	Cool, 4°C, H ₂ SO ₄ to pH<2	28 days	100 ml
Biochemical Oxygen Demand	Plastic or glass	Cool, 4°C	48 hours	500 ml
Volatile Organic Compounds	Glass, Teflon-lined septum	Cool, 4°C, HCl to pH<2 Cool, 4°C	14 days 7 days	40 ml x 2

Appendices

Collecting Oil and Grease Samples

1. Samples to be analyzed for oil and grease will be collected in one laboratory-supplied, 2-quart wide mouth glass jar.
2. The samples will be preserved in the field with sulfuric acid to reduce the pH of the sample to less than 2.
3. The samples will be cooled to approximately 4° C.

Collecting Total Suspended Solids Samples

1. Samples to be analyzed for total suspended solids will be collected in a laboratory-supplied polyethylene jar with a polyethylene lined closure.
2. The samples will be cooled to approximately 4° C.

Collecting Cyanide Samples

1. Groundwater samples to be analyzed for cyanide will be collected in a 1-liter polyethylene container with a polyethylene cap.
2. These samples will be preserved in the field with sodium hydroxide to pH greater than 12 and cooled to approximately 4°C.

Collecting Quality Control Samples

The effectiveness of the sample handling techniques is monitored by collecting both preserved and unpreserved field blank samples.

Masked duplicate samples will be collected to measure relative sampling precision. Ten percent of all samples collected are collected in duplicate. These samples are collected at the same time using the same procedures, equipment, and types of containers as the required samples. They are also

preserved in the same manner and submitted for the same analyses as the required samples.

Trip blanks are most commonly used when sampling for volatile organics. Their purpose is to determine if contamination has occurred as a result of improper sample container cleaning, contaminated blank source water, sample contamination during storage and transport due to exposure to volatile organics, or other environmental conditions during sampling. Trip blanks are prepared prior to the sampling events by the laboratory providing the sample containers. The water will be free of contaminants. The trip blanks are sealed, labeled appropriately, and transported to the field in the same containers as the sample vials. These blanks are not opened in the field. They are transferred to the ice chest designated for volatile sample storage and transport and accompany the samples to the analytical laboratory. One trip blank for each method should be provided per cooler used for storing and transporting sample containers.

Field blanks are used to evaluate the effects of on-site environmental contaminants, the purity of reagents used as preservatives or additives, and general sample container filling/collecting techniques. Field blanks are prepared on-site by filling the sample containers with analyte-free water (usually provided by the laboratory), adding appropriate preservatives and additives, sealing the containers, and completing the appropriate documentation. The field blanks will be handled in the same manner as the sample group for which they are intended (i.e., blanks will be stored and transported with the sample group). The water for VOA field blanks should be from the same source as the trip blank water. One field blank sample should be prepared per day or at a frequency of ten percent of the samples per sample event, whichever is greater.

Equipment blanks are used to evaluate the effects of on-site equipment contaminants. Their purpose is to determine if contamination has occurred as a result of improper equipment cleaning. Equipment blanks are prepared on-site by pouring analyte-free water into a clean bailer and collecting the rinsate in a sample container. The equipment blanks will be handled in the same manner as the sample group for which they are intended (i.e., blanks

will be stored and transported with the sample group). One equipment blank sample should be prepared per day or at a frequency of 10 percent of the samples per sample event, whichever is greater.

Some general considerations will be taken into account when planning and conducting sampling operations. The Sampler will take into consideration the required sample volumes, sample holding times, sample handling, and special precautions for trace contaminant sampling.

The volume of the sample obtained should be sufficient to perform all required analyses with an additional amount collected to satisfy the needs for quality control, split samples, or repeat examinations. The Laboratory Coordinator should be consulted for any specific volume requirements. Multiple sample containers are always required for VOA analyses.

The elapsed time between sample collection and initiation of each laboratory analysis will fall within a prescribed time frame. Holding times for samples required by this project are shown in Table A.8-1.

After collection, all samples should be handled as few times as possible. Samplers should use extreme care to ensure that samples are not contaminated. If samples are placed in an ice chest, Samplers should ensure that melted ice cannot cause sample containers to become submerged, as this may result in cross-contamination. Plastic bags, such as Ziplock bags, should be used when small sample containers (e.g., VOA vials) are placed in ice chests to prevent cross-contamination.

Some compounds can be detected in the parts per billion and/or parts per trillion range. Extreme care will be taken to prevent cross-contamination of these samples. A clean pair of new, disposable gloves will be worn for each sample location. Sample containers for source samples or samples suspected of containing high concentrations of contaminants are placed in separate plastic bags and coolers immediately after collecting, preserving and tagging. Sample collection activities will proceed progressively from the least contaminated area to the most contaminated area (when known).

Appendix A

Test Trench Log Form

[illegible]

Appendix B

ASTM Designation D 2488



Standard Practice for Description and Identification of Soils (Visual-Manual Procedure)¹

This standard is issued under the fixed designation D 2488; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice covers procedures for the description of soils for engineering purposes.

1.2 This practice also describes a procedure for identifying soils, at the option of the user, based on the classification system described in Test Method D 2487. The identification is based on visual examination and manual tests. It must be clearly stated in reporting an identification that it is based on visual-manual procedures.

1.2.1 When precise classification of soils for engineering purposes is required, the procedures prescribed in Test Method D 2487 shall be used.

1.2.2 In this practice, the identification portion assigning a group symbol and name is limited to soil particles smaller than 3 in. (75 mm).

1.2.3 The identification portion of this practice is limited to naturally occurring soils.

NOTE 1—This practice may be used as a descriptive system applied to such materials as shale, claystone, shells, crushed rock, etc. (See Appendix X2).

1.3 The descriptive information in this practice may be used with other soil classification systems or for materials other than naturally occurring soils.

1.4 *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of whoever uses this standard to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. For specific precautionary statements see Section 8.*

1.5 The values stated in inch-pound units are to be regarded as the standard.

2. Referenced Documents

2.1 ASTM Standards:

D 653 Terms and Symbols Relating to Soil and Rock²

D 1452 Practice for Soil Investigation and Sampling by Auger Borings²

D 1586 Method for Penetration Test and Split-Barrel Sampling of Soils²

D 1587 Practice for Thin-Walled Tube Sampling of Soils²

¹ This practice is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.07 on Identification and Classification of Soils.

Current edition approved Oct. 3, 1984. Published December 1984. Originally published as D 2488 - 66 T. Last previous edition D 2488 - 69 (1975).

² Annual Book of ASTM Standards, Vol 04.08.

D 2113 Practice for Diamond Core Drilling for Site Investigation²

D 2487 Test Method for Classification of Soils for Engineering Purposes²

3. Definitions

3.1 Except as listed below, all definitions are in accordance with Terms and Symbols D 653.

NOTE 2—For particles retained on a 3-in. (75-mm) US standard sieve, the following definitions are suggested:

Cobbles—particles of rock that will pass a 12-in. (300-mm) square opening and be retained on a 3-in. (75-mm) sieve, and

Boulders—particles of rock that will not pass a 12-in. (300-mm) square opening.

3.1.1 **clay**—soil passing a No. 200 (75- μ m) sieve that can be made to exhibit plasticity (putty-like properties) within a range of water contents, and that exhibits considerable strength when air-dry. For classification, a clay is a fine-grained soil, or the fine-grained portion of a soil, with a plasticity index equal to or greater than 4, and the plot of plasticity index versus liquid limit falls on or above the "A" line (see Fig. 3 of Test Method D 2487).

3.1.2 **gravel**—particles of rock that will pass a 3-in. (75-mm) sieve and be retained on a No. 4 (4.75-mm) sieve with the following subdivisions:

coarse—passes a 3-in. (75-mm) sieve and is retained on a 3/4-in. (19-mm) sieve.

fine—passes a 3/4-in. (19-mm) sieve and is retained on a No. 4 (4.75-mm) sieve.

3.1.3 **organic clay**—a clay with sufficient organic content to influence the soil properties. For classification, an organic clay is a soil that would be classified as a clay, except that its liquid limit value after oven drying is less than 75 % of its liquid limit value before oven drying.

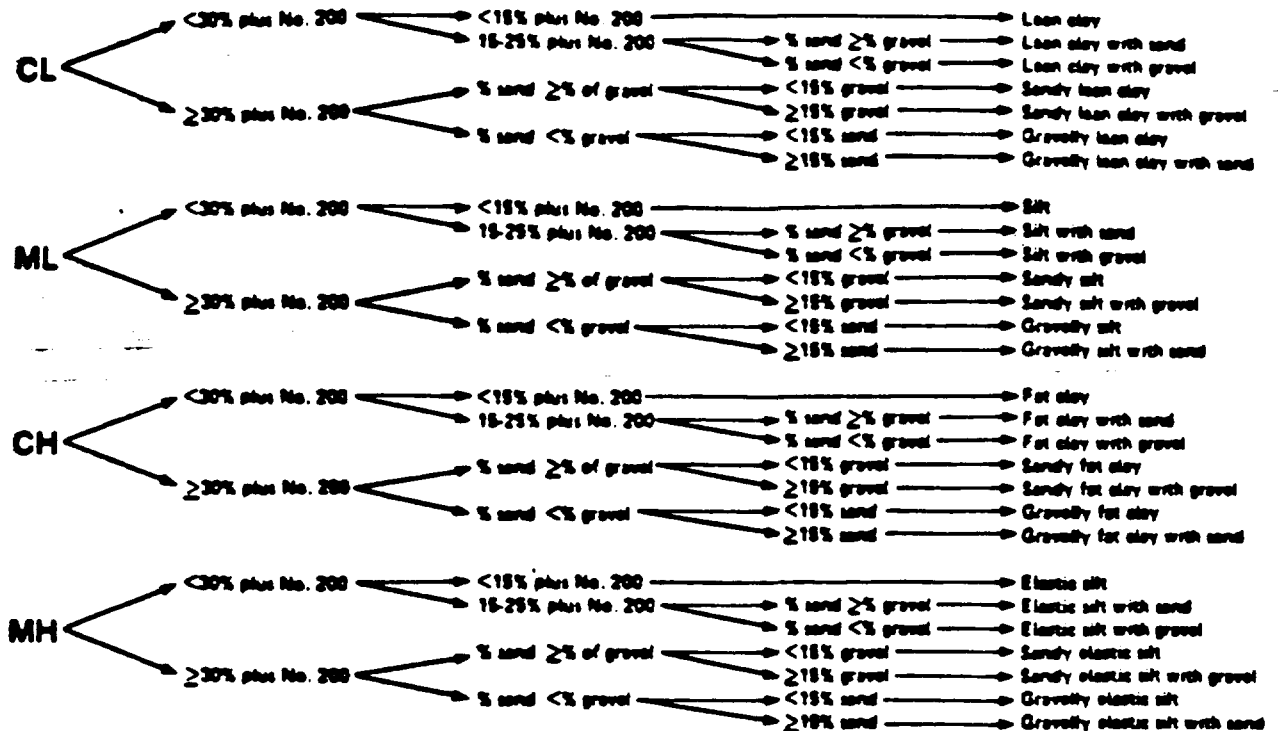
3.1.4 **organic silt**—a silt with sufficient organic content to influence the soil properties. For classification, an organic silt is a soil that would be classified as a silt except that its liquid limit value after oven drying is less than 75 % of its liquid limit value before oven drying.

3.1.5 **peat**—a soil composed primarily of vegetable tissue in various stages of decomposition usually with an organic odor, a dark brown to black color, a spongy consistency, and a texture ranging from fibrous to amorphous.

3.1.6 **sand**—particles of rock that will pass a No. 4 (4.75-mm) sieve and be retained on a No. 200 (75- μ m) sieve with the following subdivisions:

coarse—passes a No. 4 (4.75-mm) sieve and is retained on a No. 10 (2.00-mm) sieve.

medium—passes a No. 10 (2.00-mm) sieve and is retained on a No. 40 (425- μ m) sieve.

GROUP SYMBOLGROUP NAME

NOTE—Percentages are based on estimating amounts of fines, sand, and gravel to the nearest 5%.

FIG. 1a Flow Chart for Identifying Inorganic Fine-Grained Soil (80 % or more fines)

fine—passes a No. 40 (425-μm) sieve and is retained on a No. 200 (75-μm) sieve.

3.1.7 *silt*—soil passing a No. 200 (75-μm) sieve that is nonplastic or very slightly plastic and that exhibits little or no strength when air dry. For classification, a silt is a fine-grained soil, or the fine-grained portion of a soil, with a plasticity index less than 4, or the plot of plasticity index versus liquid limit falls below the "A" line (see Fig. 3 of Test Method D 2487).

4. Summary of Practice

4.1 Using visual examination and simple manual tests, this practice gives standardized criteria and procedures for describing and identifying soils.

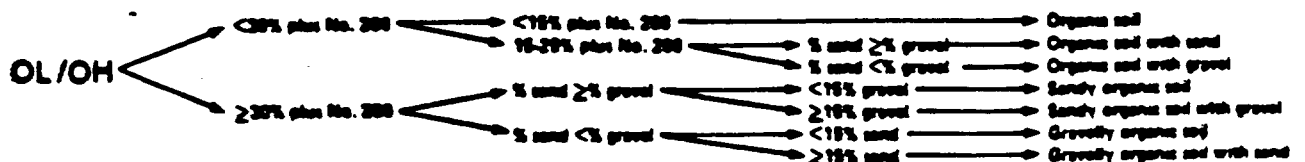
4.2 The soil can be given an identification by assigning a group symbol(s) and name. The flow charts, Figs. 1a and 1b for fine-grained soils, and Fig. 2, for coarse-grained soils, can

be used to assign the appropriate group symbol(s) and name. If the soil has properties which do not distinctly place it into a specific group, borderline symbols may be used. See Appendix X3.

NOTE 3—It is suggested that a distinction be made between *dual symbols* and *borderline symbols*.

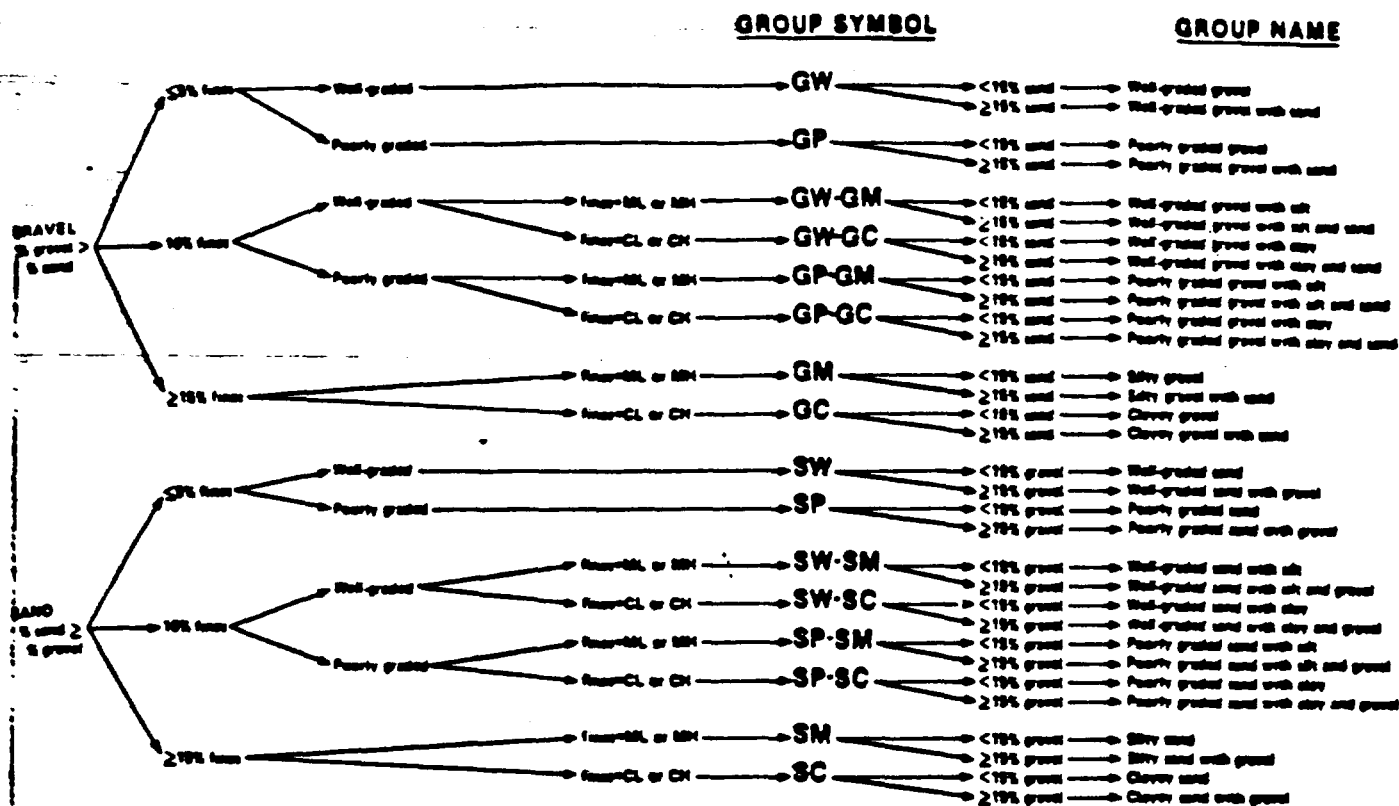
Dual Symbol—A dual symbol is two symbols separated by a hyphen. For example, GP-GM, SW-SC, CL-ML used to indicate that the soil has been identified as having the properties of a classification in accordance with Test Method D 2487 where two symbols are required. Two symbols are required when the soil has between 5 and 12 % fines or when the liquid limit and plasticity index values plot in the CL-ML area of the plasticity chart.

Borderline Symbol—A borderline symbol is two symbols separated by a slash, for example, CL/CH, GM/SM, CL/ML. A borderline symbol should be used to indicate that the soil has been identified as having properties that do not distinctly place the soil into a specific group (see Appendix X3).

GROUP SYMBOLGROUP NAME

NOTE—Percentages are based on estimating amounts of fines, sand, and gravel to the nearest 5%.

FIG. 1b Flow Chart for Identifying Organic Fine-Grained Soil (80 % or more fines)



NOTE—Percentages are based on estimating amounts of fines, sand, and gravel to the nearest 5%.

FIG. 2 Flow Chart for Identifying Coarse-Grained Soils (less than 80 % fines)

5. Significance and Use

5.1 The descriptive information required in this practice can be used to describe a soil to aid in the evaluation of its significant properties for engineering use.

5.2 The descriptive information required in this practice should be used to supplement the classification of a soil as determined by Test Method D 2487.

5.3 This practice may be used in identifying soils using the classification group symbols and names as prescribed in Test Method D 2487. Since the names and symbols used in this practice to identify the soils are the same as those used in Test Method D 2487, it shall be clearly stated in reports and all other appropriate documents, that the classification symbol and name are based on visual-manual procedures.

5.4 This practice is to be used not only for identification of soils in the field, but also in the office, laboratory, or wherever soil samples are inspected and described.

5.5 This practice has particular value in grouping similar soil samples so that only a minimum number of laboratory tests need be run for positive soil classification.

NOTE 4—The ability to describe and identify soils correctly is learned more readily under the guidance of experienced personnel, but it may also be acquired systematically by comparing numerical laboratory test results for typical soils of each type with their visual and manual characteristics.

5.6 When describing and identifying soil samples from a given boring, test pit, or group of borings or pits, it is not necessary to follow all of the procedures in this practice for every sample. Soils which appear to be similar can be grouped together; one sample completely described and

identified with the others referred to as similar based on performing only a few of the descriptive and identification procedures described in this practice.

6. Apparatus

6.1 Required Apparatus:

6.1.1 Pocket Knife or Small Spatula.

6.2 Useful Auxiliary Apparatus:

6.2.1 Small Test Tube and Stopper (or jar with a lid).

6.2.2 Small Hand Lens.

7. Reagents

7.1 Purity of Water—Unless otherwise indicated, references to water shall be understood to mean water from a city water supply or natural source, including non-potable water.

7.2 Hydrochloric Acid—A small bottle of dilute hydrochloric acid, HCl, one part HCl (10 N) to three parts water (This reagent is optional for use with this practice). See Section 8.

8. Safety Precautions

8.1 When preparing the dilute HCl solution of one part concentrated hydrochloric acid (10 N) to three parts of distilled water, slowly add acid into water following necessary safety precautions. Handle with caution and store safely. If solution comes into contact with the skin, rinse thoroughly with water.

8.2 Caution—Do not add water to acid.



FIG. 3 Typical Angularity of Bulky Grains

9. Sampling

9.1 The sample shall be considered to be representative of the stratum from which it was obtained by an appropriate, accepted, or standard procedure.

NOTE 5—Preferably, the sampling procedure should be identified as having been conducted in accordance with Practices D 1452, D 1587, or D 2113, or Method D 1586.

9.2 The sample shall be carefully identified as to origin.

NOTE 6—Remarks as to the origin may take the form of a boring number and sample number in conjunction with a job number, a geologic stratum, a pedologic horizon or a location description with respect to a permanent monument, a grid system or a station number and offset with respect to a stated centerline and a depth or elevation.

9.3 For accurate description and identification, the minimum amount of the specimen to be examined shall be in accordance with the following schedule:

Maximum Particle Size, Sieve Opening	Minimum Specimen Size, Dry Weight
4.75 mm (No. 4)	100 g (0.25 lb)
9.5 mm (¾ in.)	200 g (0.5 lb)
19.0 mm (¾ in.)	1.0 kg (2.2 lb)
38.1 mm (1½ in.)	8.0 kg (18 lb)
75.0 mm (3 in.)	40.0 kg (132 lb)

NOTE 7—If random isolated particles are encountered that are significantly larger than the particles in the soil matrix, the soil matrix can be accurately described and identified in accordance with the preceding schedule.

TABLE 1 Criteria for Describing Angularity of Coarse-Grained Particles (see Fig. 3)

Description	Criteria
Angular	Particles have sharp edges and relatively plane sides with unpolished surfaces
Subangular	Particles are similar to angular description but have rounded edges
Subrounded	Particles have nearly plane sides but have well-rounded corners and edges
Rounded	Particles have smoothly curved sides and no edges

9.4 If the field sample or specimen being examined is smaller than the minimum recommended amount, the report shall include an appropriate remark.

10. Descriptive Information for Soils

10.1 *Angularity*—Describe the angularity of the sand (coarse sizes only), gravel, cobbles, and boulders, as angular, subangular, subrounded, or rounded in accordance with the criteria in Table 1 and Fig. 3. A range of angularity may be stated, such as: subrounded to rounded.

10.2 *Shape*—Describe the shape of the gravel, cobbles, and boulders as flat, elongated, or flat and elongated if they meet the criteria in Table 2 and Fig. 4. Otherwise, do not mention the shape. Indicate the fraction of the particles that have the shape, such as: one-third of the gravel particles are flat.

10.3 *Color*—Describe the color. Color is an important property in identifying organic soils, and within a given locality it may also be useful in identifying materials of similar geologic origin. If the sample contains layers or patches of varying colors, this shall be noted and all representative colors shall be described. The color shall be described for moist samples. If the color represents a dry condition, this shall be stated in the report.

10.4 *Odor*—Describe the odor if organic or unusual. Soils containing a significant amount of organic material usually have a distinctive odor of decaying vegetation. This is especially apparent in fresh samples, but if the samples are dried, the odor may often be revived by heating a moistened

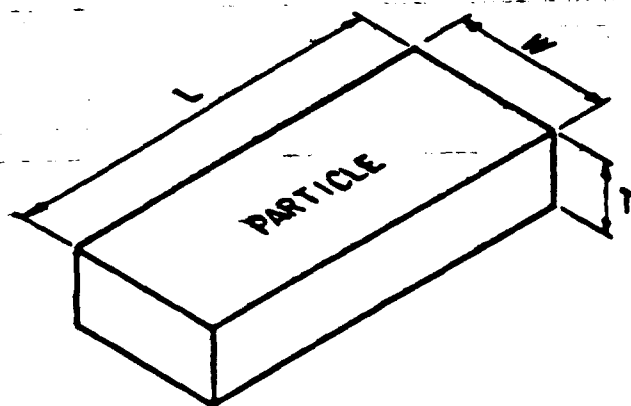
TABLE 2 Criteria for Describing Particle Shape (see Fig. 4)

The particle shape shall be described as follows where length, width and thickness refer to the greatest, intermediate, and least dimensions of a particle respectively.

Flat	Particles with width/thickness > 3
Elongated	Particles with length/width > 3
Flat and elongated	Particles meet criteria for both flat and elongated

PARTICLE SHAPE

W = WIDTH
T = THICKNESS
L = LENGTH



FLAT: $W/T > 3$
ELONGATED: $L/W > 3$
FLAT AND ELONGATED:
- meets both criteria

FIG. 4 Criteria for Particle Shape

TABLE 3 Criteria for Describing Moisture Condition

Description	Criteria
Dry	Absence of moisture, dusty, dry to the touch
Moist	Damp but no visible water
Wet	Visible free water, usually soil is below water table

sample. If the odor is unusual (petroleum product, chemical, and the like), it shall be described.

10.5 Moisture Condition—Describe the moisture condition as dry, moist, or wet, in accordance with the criteria in Table 3.

10.6 HCl Reaction—Describe the reaction with HCl as none, weak, or strong, in accordance with the criteria in Table 4. Since calcium carbonate is a common cementing agent, a report of its presence on the basis of the reaction with dilute hydrochloric acid is important.

10.7 Consistency—For intact fine-grained soil, describe the consistency as very soft, soft, firm, hard, or very hard, in accordance with the criteria in Table 5. This observation is inappropriate for soils with significant amounts of gravel.

TABLE 4 Criteria for Describing the Reaction With HCl

Description	Criteria
None	No visible reaction
Weak	Some reaction, with bubbles forming slowly
Strong	Violent reaction, with bubbles forming immediately

TABLE 5 Criteria for Describing Consistency

Description	Criteria
Very soft	Thumb will penetrate soil more than 1 in. (25 mm)
Soft	Thumb will penetrate soil about 1 in. (25 mm)
Firm	Thumb will indent soil about 1/4 in. (6 mm)
Hard	Thumb will not indent soil but readily indented with thumbnail
Very hard	Thumbnail will not indent soil

10.8 Cementation—Describe the cementation of intact coarse-grained soils as weak, moderate, or strong, in accordance with the criteria in Table 6.

10.9 Structure—Describe the structure of intact soils in accordance with the criteria in Table 7.

10.10 Range of Particle Sizes—For gravel and sand components, describe the range of particle sizes within each component as defined in 3.1.2 and 3.1.6. For example, about 20 % fine to coarse gravel, about 40 % fine to coarse sand.

10.11 Maximum Particle Size—Describe the maximum particle size found in the sample in accordance with the following information:

10.11.1 Sand Size—If the maximum particle size is a sand size, describe as fine, medium, or coarse as defined in 3.1.7. For example: maximum particle size, medium sand.

10.11.2 Gravel Size—If the maximum particle size is a gravel size, describe the maximum particle size as the smallest sieve opening that the particle will pass. For example, maximum particle size, 1 1/2 in. (will pass a 1 1/2-in. square opening but not a 3/4-in. square opening).

10.11.3 Cobble or Boulder Size—If the maximum particle size is a cobble or boulder size, describe the maximum dimension of the largest particle. For example: maximum dimension, 18 in. (450 mm).

10.12 Hardness—Describe the hardness of coarse sand and larger particles as hard, or state what happens when the particles are hit by a hammer, for example, gravel-size particles fracture with considerable hammer blow, some gravel-size particles crumble with hammer blow. "Hard" means particles do not crack, fracture, or crumble under a hammer blow.

10.13 Additional comments shall be noted, such as the presence of roots or root holes, difficulty in drilling or augering hole, caving of trench or hole, or the presence of mica.

10.14 A local or commercial name or a geologic interpretation of the soil, or both, may be added if identified as such.

10.15 A classification or identification of the soil in accordance with other classification systems may be added if identified as such.

11. Identification of Peat

11.1 A sample composed primarily of vegetable tissue in various stages of decomposition that has a fibrous to amorphous texture, usually a dark brown to black color, and an organic odor, shall be designated as a highly organic soil and shall be identified as peat, PT, and not subjected to the

TABLE 6 Criteria for Describing Cementation

Description	Criteria
Weak	Crumbles or breaks with handling or little finger pressure
Moderate	Crumbles or breaks with considerable finger pressure
Strong	Will not crumble or break with finger pressure

TABLE 7 Criteria for Describing Structure

Description	Criteria
Stratified	Alternating layers of varying material or color with layers at least 6 mm thick, note thickness
Laminated	Alternating layers of varying material or color with the layers less than 6 mm thick, note thickness
Fissured	Breaks along definite planes of fracture with little resistance to fracturing
Slickensided	Fracture planes appear polished or glossy, sometimes striated
Blocky	Cohesive soil that can be broken down into small angular lumps which resist further breakdown
Lensed	Inclusion of small pockets of different soils, such as small lenses of sand scattered through a mass of clay; note thickness
Homogeneous	Same color and appearance throughout

identification procedures described hereafter.

12. Preparation for Identification

12.1 The soil identification portion of this practice is based on the portion of the soil sample that will pass a 3-in. (75-mm) sieve. The larger than 3-in. (75-mm) particles must be removed, manually, for a loose sample, or mentally, for an intact sample before classifying the soil.

12.2 Estimate and note the percentage of cobbles and the percentage of boulders. Performed visually, these estimates will be on the basis of volume percentage.

NOTE 8—Since the percentages of the particle-size distribution in Test Method D 2487 are by dry weight, and the estimates of percentages for gravel, sand, and fines in this practice are by dry weight, it is recommended that the report state that the percentages of cobbles and boulders are by volume.

12.3 Of the fraction of the soil smaller than 3 in. (75 mm), estimate and note the percentage, by dry weight, of the gravel, sand, and fines (see Appendix X4 for suggested procedures).

NOTE 9—Since the particle-size components appear visually on the basis of volume, considerable experience is required to estimate the percentages on the basis of dry weight. Frequent comparisons with laboratory particle-size analyses should be made.

12.3.1 The percentages shall be estimated to the closest 5 %. The percentages of gravel, sand, and fines must add up to 100 %.

12.3.2 If one of the components is present but not in sufficient quantity to be considered 5 % of the smaller than 3-in. (75-mm) portion, indicate its presence by the term *trace*, for example, trace of fines. A trace is not to be considered in the total of 100 % for the components.

TABLE 8 Criteria for Describing Dry Strength

Description	Criteria
None	The dry specimen crumbles into powder with mere pressure of handling
Low	The dry specimen crumbles into powder with some finger pressure
Medium	The dry specimen breaks into pieces or crumbles with considerable finger pressure
High	The dry specimen cannot be broken with finger pressure. Specimen will break into pieces between thumb and a hard surface
Very high	The dry specimen cannot be broken between the thumb and a hard surface

13. Preliminary Identification

13.1 The soil is *fine grained* if it contains 50 % or more fines. Follow the procedures for identifying fine-grained soils of Section 14.

13.2 The soil is *coarse grained* if it contains less than 50 % fines. Follow the procedures for identifying coarse-grained soils of Section 15.

14. Procedure for Identifying Fine-Grained Soils

14.1 Select a representative sample of the material for examination. Remove particles larger than the No. 40 sieve (medium sand and larger) until a specimen equivalent to about a handful of material is available. Use this specimen for performing the dry strength, dilatancy, and toughness tests.

14.2 Dry Strength:

14.2.1 From the specimen, select enough material to mold into a ball about 1 in. (25 mm) in diameter. Mold the material until it has the consistency of putty, adding water if necessary.

14.2.2 From the molded material, make at least three test specimens. A test specimen shall be a ball of material about 1/2 in. (12 mm) in diameter. Allow the test specimens to dry in air, or sun, or by artificial means, as long as the temperature does not exceed 60°C.

14.2.3 If the test specimen contains natural dry lumps, those that are about 1/2 in. (12 mm) in diameter may be used in place of the molded balls.

NOTE 10—The process of molding and drying usually produces higher strengths than are found in natural dry lumps of soil.

14.2.4 Test the strength of the dry balls or lumps by crushing between the fingers. Note the strength as none, low, medium, high, or very high in accordance with the criteria in Table 8. If natural dry lumps are used, do not use the results of any of the lumps that are found to contain particles of coarse sand.

14.2.5 The presence of high-strength water-soluble cementing materials, such as calcium carbonate, may cause exceptionally high dry strengths. The presence of calcium carbonate can usually be detected from the intensity of the reaction with dilute hydrochloric acid (see 10.6).

14.3 Dilatancy:

14.3.1 From the specimen, select enough material to mold into a ball about 1/2 in. (12 mm) in diameter. Mold the material, adding water if necessary, until it has a soft, but not sticky, consistency.

14.3.2 Smooth the soil ball in the palm of one hand with the blade of a knife or small spatula. Shake horizontally, striking the side of the hand vigorously against the other hand several times. Note the reaction of water appearing on the surface of the soil. Squeeze the sample by closing the hand or pinching the soil between the fingers, and note the

TABLE 9 Criteria for Describing Dilatancy

Description	Criteria
None	No visible change in the specimen
Slow	Water appears slowly on the surface of the specimen during shaking and does not disappear or disappears slowly upon squeezing
Rapid	Water appears quickly on the surface of the specimen during shaking and disappears quickly upon squeezing

TABLE 10 Criteria for Describing Toughness

Description	Criteria
Low	Only slight pressure is required to roll the thread near the plastic limit. The thread and the lump are weak and soft.
Medium	Medium pressure is required to roll the thread to near the plastic limit. The thread and the lump have medium stiffness.
High	Considerable pressure is required to roll the thread to near the plastic limit. The thread and the lump have very high stiffness.

reaction as none, slow, or rapid in accordance with the criteria in Table 9. The reaction is the speed with which water appears while shaking, and disappears while squeezing.

14.4 Toughness:

14.4.1 Following the completion of the dilatancy test, the test specimen is shaped into an elongated pat and rolled by hand on a smooth surface or between the palms into a thread about $\frac{1}{8}$ in. (3 mm) in diameter. (If the sample is too wet to roll easily, it should be spread into a thin layer and allowed to lose some water by evaporation.) Fold the sample threads and reroll repeatedly until the thread crumbles at a diameter of about $\frac{1}{8}$ in. The thread will crumble at a diameter of $\frac{1}{8}$ in. when the soil is near the plastic limit. Note the pressure required to roll the thread near the plastic limit. Also, note the strength of the thread. After the thread crumbles, the pieces should be lumped together and kneaded until the lump crumbles. Note the toughness of the material during kneading.

14.4.2 Describe the toughness of the thread and lump as low, medium, or high in accordance with the criteria in Table 10.

14.5 *Plasticity*—On the basis of observations made during the toughness test, describe the plasticity of the material in accordance with the criteria given in Table 11.

14.6 Decide whether the soil is an *inorganic* or an *organic* fine-grained soil (see 14.8). If inorganic, follow the steps given in 14.7.

14.7 Identification of Inorganic Fine-Grained Soils:

14.7.1 Identify the soil as a *lean clay*, CL, if the soil has medium to high dry strength, no or slow dilatancy, and medium toughness and plasticity (see Table 12).

14.7.2 Identify the soil as a *fat clay*, CH, if the soil has high to very high dry strength, no dilatancy, and high toughness and plasticity (see Table 12).

14.7.3 Identify the soil as a *silt*, ML, if the soil has no to low dry strength, slow to rapid dilatancy, and low toughness and plasticity, or is nonplastic (see Table 12).

14.7.4 Identify the soil as an *elastic silt*, MH, if the soil has low to medium dry strength, no to slow dilatancy, and low to

TABLE 11 Criteria for Describing Plasticity

Description	Criteria
Nonplastic	A $\frac{1}{8}$ -in. (3-mm) thread cannot be rolled at any water content.
Low	The thread can barely be rolled and the lump cannot be formed when drier than the plastic limit.
Medium	The thread is easy to roll and not much time is required to reach the plastic limit. The thread cannot be rerolled after reaching the plastic limit. The lump crumbles when drier than the plastic limit.
High	It takes considerable time rolling and kneading to reach the plastic limit. The thread can be rerolled several times after reaching the plastic limit. The lump can be formed without crumbling when drier than the plastic limit.

medium toughness and plasticity (see Table 12).

NOTE 11—These properties are similar to those for a lean clay. However, the silt will dry quickly on the hand and have a smooth, silky feel when dry. Some soils that would classify as MH in accordance with the criteria in Test Method D 2487 are visually difficult to distinguish from lean clays, CL. It may be necessary to perform laboratory testing for proper identification.

14.8 Identification of Organic Fine-Grained Soils:

14.8.1 Identify the soil as an *organic soil*, OL/OH, if the soil contains enough organic particles to influence the soil properties. Organic soils usually have a dark brown to black color and may have an organic odor. Often, organic soils will change color, for example, black to brown, when exposed to the air. Some organic soils will lighten in color significantly when air dried. Organic soils normally will not have a high toughness or plasticity. The thread for the toughness test will be spongy.

NOTE 12—In some cases, through practice and experience, it may be possible to further identify the organic soils as organic silts or organic clays, OL or OH. Correlations between the dilatancy, dry strength, toughness tests, and laboratory tests can be made to identify organic soils in certain deposits of similar materials of known geologic origin.

14.9 If the soil is estimated to have 15 to 25 % sand or gravel, or both, the words "with sand" or "with gravel" (whichever is more predominant) shall be added to the group name. For example: "lean clay with sand, CL" or "silt with gravel, ML" (see Figs. 1a and 1b). If the percentage of sand is equal to the percentage of gravel, use "with sand."

14.10 If the soil is estimated to have 30 % or more sand or gravel, or both, the words "sandy" or "gravelly" shall be added to the group name. Add the word "sandy" if there appears to be more sand than gravel. Add the word "gravelly" if there appears to be more gravel than sand. For example: "sandy lean clay, CL", "gravelly fat clay, CH", or "sandy silt, ML" (see Figs. 1a and 1b). If the percentage of sand is equal to the percent of gravel, use "sandy."

15. Procedure for Identifying Coarse-Grained Soils (Contains less than 50 % fines)

15.1 The soil is a *gravel* if the percentage of gravel is estimated to be more than the percentage of sand.

15.2 The soil is a *sand* if the percentage of gravel is estimated to be equal to or less than the percentage of sand.

15.3 The soil is a *clean gravel* or *clean sand* if the percentage of fines is estimated to be 5 % or less.

15.3.1 Identify the soil as a *well-graded gravel*, GW, or as a *well-graded sand*, SW, if it has a wide range of particle sizes and substantial amounts of the intermediate particle sizes.

15.3.2 Identify the soil as a *poorly graded gravel*, GP, or as a *poorly graded sand*, SP, if it consists predominantly of one size (uniformly graded), or it has a wide range of sizes with

TABLE 12 Identification of Inorganic Fine-Grained Soils from Manual Tests

Soil Symbol	Dry Strength	Dilatancy	Toughness
ML	None to low	Slow to rapid	Low or thread cannot be formed
CL	Medium to high	None to slow	Medium
MH	Low to medium	None to slow	Low to medium
CH	High to very high	None	High

some intermediate sizes obviously missing (gap or skip graded).

15.4 The soil is either a *gravel with fines* or a *sand with fines* if the percentage of fines is estimated to be 15 % or more.

15.4.1 Identify the soil as a *clayey gravel*, GC, or a *clayey sand*, SC, if the fines are clayey as determined by the procedures in Section 14.

15.4.2 Identify the soil as a *silty gravel*, GM, or a *silty sand*, SM, if the fines are silty as determined by the procedures in Section 14.

15.5 If the soil is estimated to contain 10 % fines, give the soil a dual identification using two group symbols.

15.5.1 The first group symbol shall correspond to a clean gravel or sand (GW, GP, SW, SP) and the second symbol shall correspond to a gravel or sand with fines (GC, GM, SC, SM).

15.5.2 The group name shall correspond to the first group symbol plus the words "with clay" or "with silt" to indicate the plasticity characteristics of the fines. For example: "well-graded gravel with clay, GW-GC" or "poorly graded sand with silt, SP-SM" (see Fig. 2).

15.6 If the specimen is predominantly sand or gravel but contains an estimated 15 % or more of the other coarse-grained constituent, the words "with gravel" or "with sand" shall be added to the group name. For example: "poorly graded gravel with sand, GP" or "clayey sand with gravel, SC" (see Fig. 2).

15.7 If the field sample contains any cobbles or boulders, or both, the words "with cobbles" or "with cobbles and boulders" shall be added to the group name. For example: "silty gravel with cobbles, GM."

16. Report

16.1 The report shall include the information as to origin, and the items indicated in Table 13.

NOTE 13—Example: *Clayey Gravel with Sand and Cobbles*, GC—About 50 % fine to coarse, subrounded to subangular gravel; about 30 % fine to coarse, subrounded sand; about 20 % fines with medium plasticity, high dry strength, no dilatancy, medium toughness; weak reaction with HCl; original field sample had about 5 % (by volume) subrounded cobbles, maximum dimension, 150 mm.

In-Place Conditions—Firm, homogeneous, dry, brown
Geologic Interpretation—Alluvial fan

NOTE 14—Other examples of soil descriptions and identification are given in Appendixes X1 and X2.

NOTE 15—If desired, the percentages of gravel, sand, and fines may be stated in terms indicating a range of percentages, as follows:

Trace—Particles are present but estimated to be less than 5 %

Few—5 to 10 %

Little—15 to 25 %

Some—30 to 45 %

Mostly—50 to 100 %

16.2 If, in the soil description, the soil is identified using a classification group symbol and name as described in Test Method D 2487, it must be distinctly and clearly stated in log forms, summary tables, reports, and the like, that the symbol and name are based on visual-manual procedures.

17. Precision and Bias

17.1 This practice provides qualitative information only, therefore, a precision and bias statement is not applicable.

TABLE 13 Checklist for Description of Soils

1. Group name
2. Group symbol
3. Percent of cobbles or boulders, or both (by volume)
4. Percent of gravel, sand, or fines, or all three (by dry weight)
5. Particle-size range:
Gravel—fine, coarse
Sand—fine, medium, coarse
6. Particle angularity: angular, subangular, subrounded, rounded
7. Particle shape (if appropriate): flat, elongated, flat and elongated
8. Maximum particle size or dimension
9. Hardness of coarse sand and larger particles
10. Plasticity of fines: nonplastic, low, medium, high
11. Dry strength: none, low, medium, high, very high
12. Dilatancy: none, slow, rapid
13. Toughness: low, medium, high
14. Color (in moist condition)
15. Odor (mention only if organic or unusual)
16. Moisture: dry, moist, wet
17. Reaction with HCl: none, weak, strong
For intact samples:
18. Consistency (fine-grained soils only): very soft, soft, firm, hard, very hard
19. Structure: stratified, laminated, fissured, slickensided, lensed, homogeneous
20. Cementation: weak, moderate, strong
21. Local name
22. Geologic interpretation
23. Additional comments: presence of roots or root holes, presence of mica, gypsum, etc.; surface coatings on coarse-grained particles, caving or sloughing of auger hole or trench sides, difficulty in augering or excavating, etc.

APPENDIXES

(Nonmandatory Information)

X1. EXAMPLES OF VISUAL SOIL DESCRIPTIONS

X1.1 The following examples show how the information required in 16.1 can be reported. The information that is included in descriptions should be based on individual circumstances and need.

X1.1.1 *Well-Graded Gravel with Sand (GW)*—About 75 % fine to coarse, hard, subangular gravel; about 25 % fine to coarse, hard, subangular sand; trace of fines; maximum size, 75 mm, brown, dry; no reaction with HCl.

X1.1.2 *Silty Sand with Gravel (SM)*—About 60 % predominantly fine sand; about 25 % silty fines with low plasticity, low dry strength, rapid dilatancy, and low toughness; about 15 % fine, hard, subrounded gravel, a few gravel-size particles fractured with hammer blow; maximum size, 25 mm; no reaction with HCl (Note—Field sample size smaller than recommended).

In-Place Conditions—Firm, stratified and contains lenses

of silt 1 to 2 in. (25 to 50 mm) thick, moist, brown to gray; in-place density 106 lb/ft³; in-place moisture 9 %.

X1.1.3 Organic Soil (OL/OH)—About 100 % fines with low plasticity, slow dilatancy, low dry strength, and low toughness; wet, dark brown, organic odor, weak reaction with HCl.

X1.1.4 Silty Sand with Organic Fines (SM)—About 75 % fine to coarse, hard, subangular reddish sand; about 25 % organic and silty dark brown nonplastic fines with no dry

strength and slow dilatancy; wet; maximum size, coarse sand; weak reaction with HCl.

X1.1.5 Poorly Graded Gravel with Silt, Sand, Cobbles and Boulders (GP-GM)—About 75 % fine to coarse, hard, subrounded to subangular gravel; about 15 % fine, hard, subrounded to subangular sand; about 10 % silty nonplastic fines; moist, brown; no reaction with HCl; original field sample had about 5 % (by volume) hard, subrounded cobbles and a trace of hard, subrounded boulders, with a maximum dimension of 18 in. (450 mm).

X2. USING THE IDENTIFICATION PROCEDURE AS A DESCRIPTIVE SYSTEM FOR SHALE, CLAYSTONE, SHELLS, SLAG, CRUSHED ROCK, AND THE LIKE

X2.1 The identification procedure may be used as a descriptive system applied to materials that exist in-situ as shale, claystone, sandstone, siltstone, mudstone, etc., but convert to soils after field or laboratory processing (crushing, slaking, and the like).

X2.2 Materials such as shells, crushed rock, slag, and the like, should be identified as such. However, the procedures used in this practice for describing the particle size and plasticity characteristics may be used in the description of the material. If desired, an identification using a group name and symbol according to this practice may be assigned to aid in describing the material.

X2.3 The group symbol(s) and group names should be placed in quotation marks or noted with some type of distinguishing symbol. See examples.

X2.4 Examples of how group names and symbols can be incorporated into a descriptive system for materials that are not naturally occurring soils are as follows:

X2.4.1 Shale Chunks—Retrieved as 2 to 4-in. (50 to 100-mm) pieces of shale from power auger hole, dry, brown, no reaction with HCl. After slaking in water for 24 h, material identified as "Sandy Lean Clay (CL)"; about 60 % fines with medium plasticity, high dry strength, no dilatancy and medium toughness; about 35 % fine to medium, hard sand; about 5 % gravel-size pieces of shale.

X2.4.2 Crushed Sandstone—Product of commercial crushing operation: "Poorly Graded Sand with Silt (SP-SM)"; about 90 % fine to medium sand; about 10 % nonplastic fines; dry, reddish-brown, strong reaction with HCl.

X2.4.3 Broken Shells—About 60 % gravel-size broken shells; about 30 % sand and sand-size shell pieces; about 10 % fines: "Poorly Graded Gravel with Sand (GP)."

X2.4.4 Crushed Rock—Processed from gravel and cobbles in Pit No. 7: "Poorly Graded Gravel (GP)"; about 90 % fine, hard, angular gravel-size particles; about 10 % coarse, hard, angular sand-size particles; dry, tan; no reaction with HCl.

X3. SUGGESTED PROCEDURE FOR USING A BORDERLINE SYMBOL FOR SOILS WITH TWO POSSIBLE IDENTIFICATIONS.

X3.1 Since this practice is based on estimates of particle size distribution and plasticity characteristics, it may be difficult to clearly identify the soil as belonging to one category. To indicate that the soil may fall into one of two possible basic groups, a borderline symbol may be used with the two symbols separated by a slash. For example: SC/CL or CL/CH.

X3.1.1 A borderline symbol may be used when the percentage of fines is estimated to be between 45 and 55 %. One symbol should be for a coarse-grained soil with fines and the other for a fine-grained soil. For example: GM/ML or CL/SC.

X3.1.2 A borderline symbol may be used when the percentage of sand and the percentage of gravel are estimated to be about the same. For example: GP/SP, SC/GC, GM/SM. It is practically impossible to have a soil that would have a borderline symbol of GW/SW.

X3.1.3 A borderline symbol may be used when the soil could be either well graded or poorly graded. For example: GW/GP, SW/SP.

X3.1.4 A borderline symbol may be used when the soil could either be a silt or a clay. For example: CL/ML, CH/MH, SC/SM.

X3.1.5 A borderline symbol may be used when a fine-grained soil has properties that indicate that it is at the boundary between a soil of low compressibility and a soil of high compressibility. For example: CL/CH, MH/ML.

X3.2 The order of the borderline symbols should reflect similarity to surrounding or adjacent soils. For example: soils in a borrow area have been identified as CH. One sample is considered to have a borderline symbol of CL and CH. To show similarity, the borderline symbol should be CH/CL.

X3.3 The group name for a soil with a borderline symbol should be the group name for the first symbol, except for:

CL/CH lean to fat clay
ML/CL clayey silt
CL/ML silty clay

X3.4 The use of a borderline symbol should not be used indiscriminately. Every effort shall be made to first place the soil into a single group.

X4. SUGGESTED PROCEDURES FOR ESTIMATING THE PERCENTAGES OF GRAVEL, SAND, AND FINES IN A SOIL SAMPLE

X4.1 Jar Method—The relative percentage of coarse- and fine-grained material may be estimated by thoroughly shaking a mixture of soil and water in a test tube or jar, and then allowing the mixture to settle. The coarse particles will fall to the bottom and successively finer particles will be deposited with increasing time; the sand sizes will fall out of suspension in 20 to 30 s. The relative proportions can be estimated from the relative volume of each size separate. This method should be correlated to particle-size laboratory determinations.

X4.2 Visual Method—Mentally visualize the gravel size particles placed in a sack (or other container) or sacks. Then, do the same with the sand size particles and the fines. Then, mentally compare the number of sacks to estimate the percentage of plus No. 4 sieve size and minus No. 4 sieve size

present. The percentages of sand and fines in the minus sieve size No. 4 material can then be estimated from the wash test (X4.3).

X4.3 Wash Test (for relative percentages of sand and fines)—Select and moisten enough minus No. 4 sieve size material to form a 1-in (25-mm) cube of soil. Cut the cube in half, set one-half to the side, and place the other half in a small dish. Wash and decant the fines out of the material in the dish until the wash water is clear and then compare the two samples and estimate the percentage of sand and fines. Remember that the percentage is based on weight, not volume. However, the volume comparison will provide a reasonable indication of grain size percentages.

X4.3.1 While washing, it may be necessary to break down lumps of fines with the finger to get the correct percentages.

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This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, 1916 Race St., Philadelphia, PA 19103.

Appendix C

Soil Boring Log Forms

BORING LOG

PROJECT:
DATE STARTED:
DATE COMPLETED:
FIELD INSPECTOR:
CREW CHIEF:

BORING NO.:

RISER PIPE ELEVATION:

GROUND SURFACE ELEVATION:

Depth (feet)	Net OVA (ppm)	Blows Per 6"	Sample Type	Water Content	Profile	DESCRIPTION OF MATERIALS AND REMARKS
0						
5						
10						
15						
20						
25						
30						

COMMENT:

Sheet of

SOIL BORING DATA SHEET

BARR ENGINEERING CO.

PROJECT _____ LOCATION _____
 PROJECT NO. _____ BORING NO. _____ BORING METHOD _____
 DATE STARTED _____ DATE COMPLETED _____
 FIELD INSPECTOR _____ CREW CHIEF _____
 CONTRACTOR _____ DRILL RIG _____
 WATER LEVEL _____ FT. ELEVATION _____ FT.

Sample # _____ Interval _____ - _____ Ft. Recovery _____ Date Collected ____/____/____

Sample Type: _____ Split Barrel _____ Grab _____ Thinwall _____ Blow Count: _____ - _____ - _____

1. Group Name (2. Group Symbol) _____ ()

3. _____ % Cobbles, _____ % Boulders

4. _____ % Gravel, _____ % Sand, _____ % Fines; or _____ % of all these

5. Particle Size Range:

Gravel: _____ Fine _____ Coarse

Sand: _____ Fine _____ Medium _____ Coarse

6. Particle Angularity: _____ Angular _____ Subangular _____ Subrounded _____ Rounded

7. Particle Shape: _____ Flat _____ Elongated _____ Flat & Elongated

8. Maximum Particle Size or Dimension: _____

9. Hardness of Coarse Sand and Larger Particles: _____

10. Plasticity of Fines: _____ Non-Plastic _____ Low _____ Medium _____ High

11. Dry Strength: _____ None _____ Low _____ Medium _____ High _____ Very High

12. Dilatency: _____ None _____ Slow _____ Rapid

13. Toughness: _____ Low _____ Medium _____ High

14. Color (moist): _____ ()

15. Odor: _____

16. Moisture: _____ Dry _____ Moist _____ Wet

17. Reaction with HCl: _____ None _____ Weak _____ Strong

FOR INTACT SAMPLES:

18. Consistency: _____ Very Soft _____ Soft _____ Firm _____ Hard _____ Very Hard

19. Structure: _____ Stratified _____ Laminated _____ Fissured _____ Slickensided

_____ Lensed _____ Homogeneous

20. Cementation: _____ Weak _____ Moderate _____ Strong

21. Local Name: _____

22. Geologic Interpretation: _____

23. Additional Comments:



Appendix D

ASTM Designation D 1586

Standard Method for Penetration Test and Split-Barrel Sampling of Soils¹

This standard is issued under the fixed designation D 1586; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

This method has been approved for use by agencies of the Department of Defense and for listing in the DOD Index of Specifications and Standards.

1. Scope

1.1 This method describes the procedure, generally known as the Standard Penetration Test (SPT), for driving a split-barrel sampler to obtain a representative soil sample and a measure of the resistance of the soil to penetration of the sampler.

1.2 *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of whoever uses this standard to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* For a specific precautionary statement, see 5.4.1.

1.3 The values stated in inch-pound units are to be regarded as the standard.

2. Referenced Documents

2.1 ASTM Standards:

D2487 Test Method for Classification of Soils for Engineering Purposes²

D2488 Practice for Description and Identification of Soils (Visual-Manual Procedure)²

D4220 Practices for Preserving and Transporting Soil Samples²

3. Descriptions of Terms Specific to This Standard

3.1 *anvil*—that portion of the drive-weight assembly which the hammer strikes and through which the hammer energy passes into the drill rods.

3.2 *cathead*—the rotating drum or windlass in the rope-cathead lift system around which the operator wraps a rope to lift and drop the hammer by successively tightening and loosening the rope turns around the drum.

3.3 *drill rods*—rods used to transmit downward force and torque to the drill bit while drilling a borehole.

3.4 *drive-weight assembly*—a device consisting of the hammer, hammer fall guide, the anvil, and any hammer drop system.

3.5 *hammer*—that portion of the drive-weight assembly consisting of the 140 ± 2 lb (63.5 ± 1 kg) impact weight which is successively lifted and dropped to provide the energy

that accomplishes the sampling and penetration.

3.6 *hammer drop system*—that portion of the drive-weight assembly by which the operator accomplishes the lifting and dropping of the hammer to produce the blow.

3.7 *hammer fall guide*—that part of the drive-weight assembly used to guide the fall of the hammer.

3.8 *N-value*—the blowcount representation of the penetration resistance of the soil. The *N-value*, reported in blows per foot, equals the sum of the number of blows required to drive the sampler over the depth interval of 6 to 18 in. (150 to 450 mm) (see 7.3).

3.9 ΔN —the number of blows obtained from each of the 6-in. (150-mm) intervals of sampler penetration (see 7.3).

3.10 *number of rope turns*—the total contact angle between the rope and the cathead at the beginning of the operator's rope slackening to drop the hammer, divided by 360° (see Fig. 1).

3.11 *sampling rods*—rods that connect the drive-weight assembly to the sampler. Drill rods are often used for this purpose.

3.12 *SPT*—abbreviation for Standard Penetration Test, a term by which engineers commonly refer to this method.

4. Significance and Use

4.1 This method provides a soil sample for identification purposes and for laboratory tests appropriate for soil obtained from a sampler that may produce large shear strain disturbance in the sample.

4.2 This method is used extensively in a great variety of geotechnical exploration projects. Many local correlations and widely published correlations which relate SPT blowcount, or *N-value*, and the engineering behavior of earthworks and foundations are available.

5. Apparatus

5.1 *Drilling Equipment*—Any drilling equipment that provides at the time of sampling a suitably clean open hole before insertion of the sampler and ensures that the penetration test is performed on undisturbed soil shall be acceptable. The following pieces of equipment have proven to be suitable for advancing a borehole in some subsurface conditions.

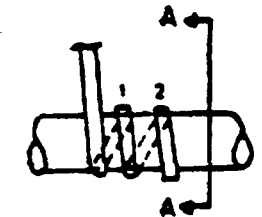
5.1.1 *Drag, Chopping, and Fishtail Bits*, less than 6.5 in. (162 mm) and greater than 2.2 in. (56 mm) in diameter may be used in conjunction with open-hole rotary drilling or casing-advancement drilling methods. To avoid disturbance of the underlying soil, bottom discharge bits are not permitted; only side discharge bits are permitted.

5.1.2 *Roller-Cone Bits*, less than 6.5 in. (162 mm) and

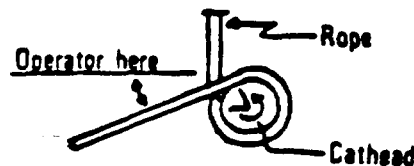
¹ This method is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.02 on Sampling and Related Field Testing for Soil Investigations.

Current edition approved Sept. 11, 1984. Published November 1984. Originally published as D 1586 - 58 T. Last previous edition D 1586 - 67 (1974).

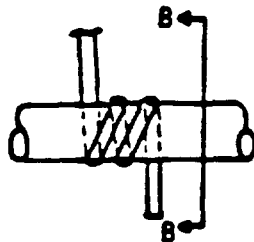
² Annual Book of ASTM Standards, Vol 04.08.



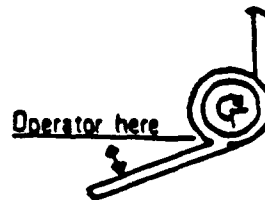
(a) counterclockwise rotation
approximately $1\frac{1}{2}$ turns



Section A-A



(b) clockwise rotation
approximately $2\frac{1}{2}$ turns



Section B-B

FIG. 1 Definitions of the Number of Rope Turns and the Angle for (a) Counterclockwise Rotation and (b) Clockwise Rotation of the Cathead

greater than 2.2 in. (56 mm) in diameter may be used in conjunction with open-hole rotary drilling or casing-advance-ment drilling methods if the drilling fluid discharge is deflected.

5.1.3 *Hollow-Stem Continuous Flight Augers*, with or without center bit assembly, may be used to drill the boring. The inside diameter of the hollow-stem augers shall be less than 6.5 in. (162 mm) and greater than 2.2 in. (56 mm).

5.1.4 *Solid, Continuous Flight, Bucket and Hand Augers*, less than 6.5 in. (162 mm) and greater than 2.2 in. (56 mm) in diameter may be used if the soil on the side of the boring does not cave onto the sampler or sampling rods during sampling.

5.2 *Sampling Rods*—Flush-joint steel drill rods shall be used to connect the split-barrel sampler to the drive-weight assembly. The sampling rod shall have a stiffness (moment of inertia) equal to or greater than that of parallel wall "A" rod (a steel rod which has an outside diameter of $1\frac{1}{2}$ in. (41.2 mm) and an inside diameter of $1\frac{1}{4}$ in. (28.5 mm)).

NOTE 1—Recent research and comparative testing indicates the type rod used, with stiffness ranging from "A" size rod to "N" size rod, will usually have a negligible effect on the *N*-values to depths of at least 100 ft (30 m).

5.3 *Split-Barrel Sampler*—The sampler shall be constructed with the dimensions indicated in Fig. 2. The driving shoe shall be of hardened steel and shall be replaced or repaired when it becomes dented or distorted. The use of liners to produce a constant inside diameter of $1\frac{1}{2}$ in. (35

mm) is permitted, but shall be noted on the penetration record if used. The use of a sample retainer basket is permitted, and should also be noted on the penetration record if used.

NOTE 2—Both theory and available test data suggest that *N*-values may increase between 10 to 30 % when liners are used.

5.4 Drive-Weight Assembly:

5.4.1 *Hammer and Anvil*—The hammer shall weigh 140 ± 2 lb (63.5 ± 1 kg) and shall be a solid rigid metallic mass. The hammer shall strike the anvil and make steel on steel contact when it is dropped. A hammer fall guide permitting a free fall shall be used. Hammers used with the cathead and rope method shall have an unimpeded overlift capacity of at least 4 in. (100 mm). For safety reasons, the use of a hammer assembly with an internal anvil is encouraged.

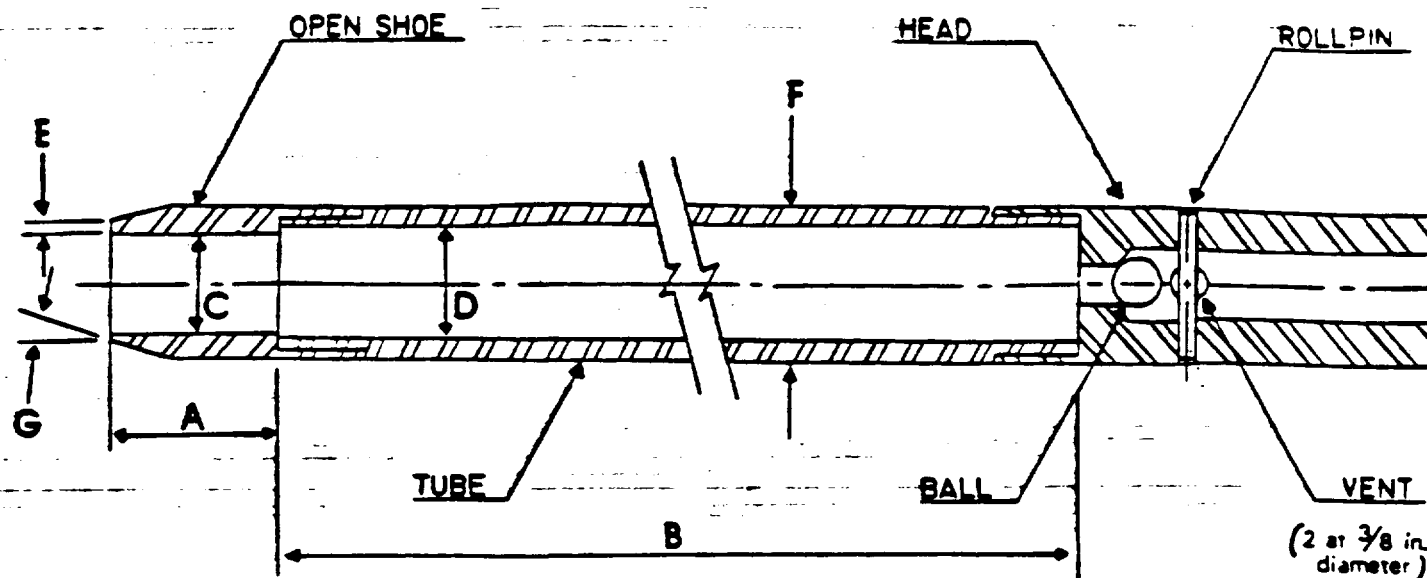
NOTE 3—It is suggested that the hammer fall guide be permanently marked to enable the operator or inspector to judge the hammer drop height.

5.4.2 *Hammer Drop System*—Rope-cathead, trip, semi-automatic, or automatic hammer drop systems may be used, providing the lifting apparatus will not cause penetration of the sampler while re-engaging and lifting the hammer.

5.5 *Accessory Equipment*—Accessories such as labels, sample containers, data sheets, and groundwater level measuring devices shall be provided in accordance with the requirements of the project and other ASTM standards.

6. Drilling Procedure

6.1 The boring shall be advanced incrementally to permit intermittent or continuous sampling. Test intervals and lo-



- A = 1.0 to 2.0 in. (25 to 50 mm)
 B = 18.0 to 30.0 in. (0.457 to 0.762 m)
 C = 1.375 ± 0.005 in. (34.93 ± 0.13 mm)
 D = $1.50 \pm 0.05 - 0.00$ in. ($38.1 \pm 1.3 - 0.0$ mm)
 E = 0.10 ± 0.02 in. (2.54 ± 0.25 mm)
 F = $2.00 \pm 0.05 - 0.00$ in. ($50.8 \pm 1.3 - 0.0$ mm)
 G = 16.0° to 23.0°

The $1\frac{1}{4}$ in. (38 mm) inside diameter split barrel may be used with a 16-gage wall thickness split liner. The penetrating end of the drive shoe may be slightly rounded. Metal or plastic retainers may be used to retain soil samples.

FIG. 2 Split-Barrel Sampler

cations are normally stipulated by the project engineer or geologist. Typically, the intervals selected are 5 ft (1.5 m) or less in homogeneous strata with test and sampling locations at every change of strata.

6.2 Any drilling procedure that provides a suitably clean and stable hole before insertion of the sampler and assures that the penetration test is performed on essentially undisturbed soil shall be acceptable. Each of the following procedures have proven to be acceptable for some subsurface conditions. The subsurface conditions anticipated should be considered when selecting the drilling method to be used.

6.2.1 Open-hole rotary drilling method.

6.2.2 Continuous flight hollow-stem auger method.

6.2.3 Wash boring method.

6.2.4 Continuous flight solid auger method.

6.3 Several drilling methods produce unacceptable borings. The process of jetting through an open tube sampler and then sampling when the desired depth is reached shall not be permitted. The continuous flight solid auger method shall not be used for advancing the boring below a water table or below the upper confining bed of a confined non-cohesive stratum that is under artesian pressure. Casing may not be advanced below the sampling elevation prior to sampling. Advancing a boring with bottom discharge bits is not permissible. It is not permissible to advance the boring for subsequent insertion of the sampler solely by means of previous sampling with the SPT sampler.

6.4 The drilling fluid level within the boring or hollow-stem augers shall be maintained at or above the in situ groundwater level at all times during drilling, removal of drill rods, and sampling.

7. Sampling and Testing Procedure

7.1 After the boring has been advanced to the desired sampling elevation and excessive cuttings have been removed, prepare for the test with the following sequence of operations.

7.1.1 Attach the split-barrel sampler to the sampling rods and lower into the borehole. Do not allow the sampler to drop onto the soil to be sampled.

7.1.2 Position the hammer above and attach the anvil to the top of the sampling rods. This may be done before the sampling rods and sampler are lowered into the borehole.

7.1.3 Rest the dead weight of the sampler, rods, anvil, drive weight on the bottom of the boring and apply a seating blow. If excessive cuttings are encountered at the bottom of the boring, remove the sampler and sampling rods from the boring and remove the cuttings.

7.1.4 Mark the drill rods in three successive 6-in. (0.15-m) increments so that the advance of the sampler under the impact of the hammer can be easily observed for each 6-in. (0.15-m) increment.

7.2 Drive the sampler with blows from the 140-lb (63.5-kg) hammer and count the number of blows applied in each 6-in. (0.15-m) increment until one of the following occurs:

7.2.1 A total of 50 blows have been applied during any one of the three 6-in. (0.15-m) increments described in 7.1.4.

7.2.2 A total of 100 blows have been applied.

7.2.3 There is no observed advance of the sampler during the application of 10 successive blows of the hammer.

7.2.4 The sampler is advanced the complete 18 in. (0.45 m) without the limiting blow counts occurring as described in 7.2.1, 7.2.2, or 7.2.3.

7.3 Record the number of blows required to effect each 6

is considered to be a seating drive. The sum of the number of blows required for the second and third 6 in. of penetration is termed the "standard penetration resistance," or the "*N*-value." If the sampler is driven less than 18 in. (0.45 m), as permitted in 7.2.1, 7.2.2, or 7.2.3, the number of blows per each complete 6-in. (0.15-m) increment and per each partial increment shall be recorded on the boring log. For partial increments, the depth of penetration shall be reported to the nearest 1 in. (25 mm), in addition to the number of blows. If the sampler advances below the bottom of the boring under the static weight of the drill rods or the weight of the drill rods plus the static weight of the hammer, this information should be noted on the boring log.

7.4 The raising and dropping of the 140-lb (63.5-kg) hammer shall be accomplished using either of the following two methods:

7.4.1 By using a trip, automatic, or semi-automatic hammer drop system which lifts the 140-lb (63.5-kg) hammer and allows it to drop 30 ± 1.0 in. (0.76 m \pm 25 mm) unimpeded.

7.4.2 By using a cathead to pull a rope attached to the hammer. When the cathead and rope method is used the system and operation shall conform to the following:

7.4.2.1 The cathead shall be essentially free of rust, oil, or grease and have a diameter in the range of 6 to 10 in. (150 to 250 mm).

7.4.2.2 The cathead should be operated at a minimum speed of rotation of 100 RPM, or the approximate speed of rotation shall be reported on the boring log.

7.4.2.3 No more than $2\frac{1}{4}$ rope turns on the cathead may be used during the performance of the penetration test, as shown in Fig. 1.

NOTE 4—The operator should generally use either $1\frac{1}{4}$ or $2\frac{1}{4}$ rope turns, depending upon whether or not the rope comes off the top ($1\frac{1}{4}$ turns) or the bottom ($2\frac{1}{4}$ turns) of the cathead. It is generally known and accepted that $2\frac{1}{4}$ or more rope turns considerably impedes the fall of the hammer and should not be used to perform the test. The cathead rope should be maintained in a relatively dry, clean, and unfayed condition.

7.4.2.4 For each hammer blow, a 30-in. (0.76-m) lift and drop shall be employed by the operator. The operation of pulling and throwing the rope shall be performed rhythmically without holding the rope at the top of the stroke.

7.5 Bring the sampler to the surface and open. Record the percent recovery or the length of sample recovered. Describe the soil samples recovered as to composition, color, stratification, and condition, then place one or more representative portions of the sample into sealable moisture-proof containers (jars) without ramming or distorting any apparent stratification. Seal each container to prevent evaporation of soil moisture. Affix labels to the containers bearing job designation, boring number, sample depth, and the blow count per 6-in. (0.15-m) increment. Protect the samples against extreme temperature changes. If there is a soil change within the

the sampler barrel.

8. Report

8.1 Drilling information shall be recorded in the field and shall include the following:

8.1.1 Name and location of job,

8.1.2 Names of crew,

8.1.3 Type and make of drilling machine,

8.1.4 Weather conditions,

8.1.5 Date and time of start and finish of boring,

8.1.6 Boring number and location (station and coordinates, if available and applicable),

8.1.7 Surface elevation, if available,

8.1.8 Method of advancing and cleaning the boring,

8.1.9 Method of keeping boring open,

8.1.10 Depth of water surface and drilling depth at the time of a noted loss of drilling fluid, and time and date when reading or notation was made,

8.1.11 Location of strata changes,

8.1.12 Size of casing, depth of cased portion of boring,

8.1.13 Equipment and method of driving sampler,

8.1.14 Type sampler and length and inside diameter of barrel (note use of liners),

8.1.15 Size, type, and section length of the sampling rods, and

8.1.16 Remarks.

8.2 Data obtained for each sample shall be recorded in the field and shall include the following:

8.2.1 Sample depth and, if utilized, the sample number,

8.2.2 Description of soil,

8.2.3 Strata changes within sample,

8.2.4 Sampler penetration and recovery lengths, and

8.2.5 Number of blows per 6-in. (0.15-m) or partial increment.

9. Precision and Bias

9.1 Variations in *N*-values of 100 % or more have been observed when using different standard penetration test apparatus and drillers for adjacent borings in the same soil formation. Current opinion, based on field experience, indicates that when using the same apparatus and driller, *N*-values in the same soil can be reproduced with a coefficient of variation of about 10 %.

9.2 The use of faulty equipment, such as an extremely massive or damaged anvil, a rusty cathead, a low speed cathead, an old, oily rope, or massive or poorly lubricated rope sheaves can significantly contribute to differences in *N*-values obtained between operator-drill rig systems.

9.3 The variability in *N*-values produced by different drill rigs and operators may be reduced by measuring that part of the hammer energy delivered into the drill rods from the sampler and adjusting *N* on the basis of comparative energies. A method for energy measurement and *N*-value adjustment is currently under development.

The American Society for Testing and Materials takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, 1916 Race St., Philadelphia, PA 19103.

Appendix E

Well Log Form

WELL LOG

BARR ENGINEERING CO.
Minneapolis, Minnesota

Project _____ Well No. _____
Date Started _____
Date Completed _____ Riser Pipe Elevation _____
Field Inspector _____
Crew Chief _____ Ground Surface Elevation _____

BOREHOLE CONSTRUCTION NOTES	LITHOLOGY	WELL CONSTRUCTION	WELL CONSTRUCTION NOTES

Comments:

Sheet ____ of ____

Appendix F

Field Log Data Sheet

Engineering Company

Station: _____

Client _____ **Project No.** | | / | | | | | | | | | |

Location: _____ **Date:** __/__/__ **Sample Time:** _____

General	Stabilization Test						
		TIME/ VOLUME	TEMP CENT.	COND. umhos	COND. @ 25	pH	Ek
Barr Lock: Y N							
Casing Dia:							
Static Depth		1.					
Total Depth:		2.					
Water Depth:		3.					
Well Volume:		4.					
Purge Method:		5.					
Samp. Method:		6.					
Start Time:		7.					
Stop Time:		Appearance					
Duration:		Odor					
Rate, gpm:		Comments					
Volume Purged:							
Samplers:		Others Present:					
gen _____ VOC _____ COD _____ TOC _____ semi-volatile _____ f. metal _____ t. metal _____							
nitro _____ cyanide _____ oil & grease _____ 200 ml filter _____ 500 ml filter _____							
others _____							

Appendix G

Water Level Data Sheet

WATER LEVEL DATA SHEET

PROJECT NAME _____

SAMPLERS _____

DATE _____

PAGE _____ OF _____

[illegible]

Appendix H

ASTM Designation D 1587



Standard Practice for Thin-Walled Tube Sampling of Soils¹

This standard is issued under the fixed designation D 1587; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

This practice has been approved for use by agencies of the Department of Defense and for listing in the DOD Index of Specifications and Standards.

1. Scope

1.1 This practice covers a procedure for using a thin-walled metal tube to recover relatively undisturbed soil samples suitable for laboratory tests of structural properties. Thin-walled tubes used in piston, plug, or rotary-type samplers, such as the Denison or Pitcher, must comply with the portions of this practice which describe the thin-walled tubes (5.3).

NOTE 1—This practice does not apply to liners used within the above samplers.

2. Referenced Documents

2.1 ASTM Standards:

D 2488 Practice for Description and Identification of Soils (Visual-Manual Procedure)²

D 3550 Practice for Ring-Lined Barrel Sampling of Soils²

D 4220 Practices for Preserving and Transporting Soil Samples²

3. Summary of Practice

3.1 A relatively undisturbed sample is obtained by pressing a thin-walled metal tube into the in-situ soil, removing the soil-filled tube, and sealing the ends to prevent the soil from being disturbed or losing moisture.

4. Significance and Use

4.1 This practice, or Practice D 3550, is used when it is necessary to obtain a relatively undisturbed specimen suitable for laboratory tests of structural properties or other tests that might be influenced by soil disturbance.

5. Apparatus

5.1 *Drilling Equipment*—Any drilling equipment may be used that provides a reasonably clean hole; that does not disturb the soil to be sampled; and that does not hinder the penetration of the thin-walled sampler. Open borehole diameter and the inside diameter of driven casing or hollow stem auger shall not exceed 3.5 times the outside diameter of the thin-walled tube.

5.2 *Sampler Insertion Equipment*, shall be adequate to provide a relatively rapid continuous penetration force. For hard formations it may be necessary, although not recommended, to drive the thin-walled tube sampler.

5.3 *Thin-Walled Tubes*, should be manufactured as shown in Fig. 1. They should have an outside diameter of 2 to 5 in. and be made of metal having adequate strength for use in the soil and formation intended. Tubes shall be clean and free of all surface irregularities including projecting weld seams.

5.3.1 *Length of Tubes*—See Table 1 and 6.4.

5.3.2 *Tolerances*, shall be within the limits shown in Table 1.

5.3.3 *Inside Clearance Ratio*, should be 1 % or as specified by the engineer or geologist for the soil and formation to be sampled. Generally, the inside clearance ratio used should increase with the increase in plasticity of the soil being sampled. See Fig. 1 for definition of inside clearance ratio.

5.3.4 *Corrosion Protection*—Corrosion, whether from galvanic or chemical reaction, can damage or destroy both the thin-walled tube and the sample. Severity of damage is a function of time as well as interaction between the sample and the tube. Thin-walled tubes should have some form of protective coating. Tubes which will contain samples for more than 72 h shall be coated. The type of coating to be used may vary depending upon the material to be sampled. Coatings may include a light coat of lubricating oil, lacquer, epoxy, Teflon, and others. Type of coating must be specified by the engineer or geologist if storage will exceed 72 h. Plating of the tubes or alternate base metals may be specified by the engineer or geologist.

5.4 *Sampler Head*, serves to couple the thin-walled tube to the insertion equipment and, together with the thin-walled tube, comprises the thin-walled tube sampler. The sampler head shall contain a suitable check valve and a venting area to the outside equal to or greater than the area through the check valve. Attachment of the head to the tube shall be concentric and coaxial to assure uniform application of force to the tube by the sampler insertion equipment.

6. Procedure

6.1 Clean out the borehole to sampling elevation using whatever method is preferred that will ensure the material to be sampled is not disturbed. If groundwater is encountered, maintain the liquid level in the borehole at or above ground water level during the sampling operation.

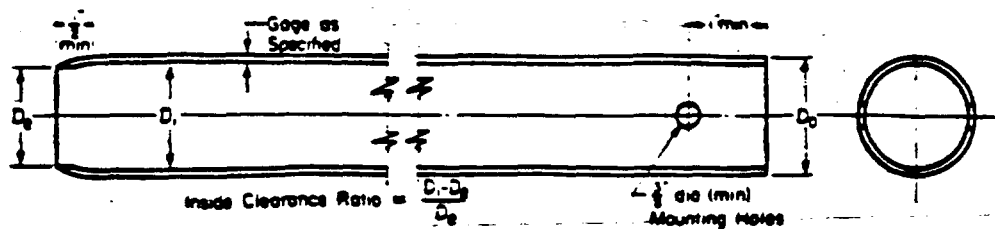
6.2 Bottom discharge bits are not permitted. Side discharge bits may be used, with caution. Jetting through an open-tube sampler to clean out the borehole to sampling elevation is not permitted. Remove loose material from the center of a casing or hollow stem auger as carefully as possible to avoid disturbance of the material to be sampled.

NOTE 2—Roller bits are available in downward-jetting and diffused-

¹ This practice is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.02 on Sampling and Related Field Testing for Soil Investigations.

Current edition approved Aug. 17, 1983. Published October 1983. Originally published as D 1587-58T. Last previous edition D 1587-74.

² Annual Book of ASTM Standards, Vol 04.08.



NOTE 1—Minimum of two mounting holes on opposite sides for 2 to 3½ in. sampler.
NOTE 2—Minimum of four mounting holes spaced at 90° for samplers 4 in. and larger.
NOTE 3—Tube held with hardened screws.

NOTE 4—Two-inch outside-diameter tubes are specified with an 18-gage wall thickness to comply with area ratio criteria accepted for "undisturbed samples." Users are advised that such tubing is difficult to locate and can be extremely expensive in small quantities. Sixteen-gage tubes are generally readily available.

Metric Equivalents

in.	mm
¾	8.77
1	12.7
2	25.4
3½	88.9
4	101.6

FIG. 1 Thin-Walled Tube for Sampling

TABLE 1 Suitable Thin-Walled Steel Sample Tubes^a

Outside diameter:			
in.	2	3	5
mm	50.8	76.2	127
Wall thickness:			
8wg	18	18	11
in.	0.049	0.065	0.120
mm	1.24	1.65	3.05
Tube length:			
in.	36	36	54
m	0.91	0.91	1.45
Clearance ratio, %	1	1	1

^a The three diameters recommended in Table 1 are indicated for purposes of standardization, and are not intended to indicate that sampling tubes of intermediate or larger diameters are not acceptable. Lengths of tubes shown are illustrative. Proper lengths to be determined as suited to field conditions.

TABLE 2 Dimensional Tolerances for Thin-Walled Tubes

Nominal Tube Diameters from Table 1^a Tolerances, in.

Size Outside Diameter	2	3	5
Outside diameter	+0.007 -0.000	+0.010 -0.000	+0.015 -0.000
Inside diameter	+0.000 -0.007	+0.000 -0.010	+0.000 -0.015
Wall thickness	±0.007	±0.010	±0.015
Ovality	0.015	0.020	0.030
Straightness	0.030/r	0.030/r	0.030/r

^a Intermediate or larger diameters should be proportional. Tolerances shown are essentially standard commercial manufacturing tolerances for seamless steel mechanical tubing. Specify only two of the first three tolerances; that is, O.D. and I.D., or O.D. and Wall, or I.D. and Wall.

jet configurations. Downward-jetting configuration rock bits are not acceptable. Diffuse-jet configurations are generally acceptable.

6.3 Place the sample tube so that its bottom rests on the bottom of the hole. Advance the sampler without rotation by a continuous relatively rapid motion.

6.4 Determine the length of advance by the resistance and condition of the formation, but the length shall never exceed 5 to 10 diameters of the tube in sands and 10 to 15 diameters

of the tube in clays.

NOTE 3—Weight of sample, laboratory handling capabilities, transportation problems, and commercial availability of tubes will generally limit maximum practical lengths to those shown in Table 1.

6.5 When the formation is too hard for push-type insertion, the tube may be driven or Practice D 3550 may be used. Other methods, as directed by the engineer or geologist, may be used. If driving methods are used, the data regarding weight and fall of the hammer and penetration achieved must be shown in the report. Additionally, that tube must be prominently labeled a "driven sample."

6.6 In no case shall a length of advance be greater than the sample-tube length minus an allowance for the sampler head and a minimum of 3 in. for sludge-end cuttings.

NOTE 4—The tube may be rotated to shear bottom of the sample after pressing is complete.

6.7 Withdraw the sampler from the formation as carefully as possible in order to minimize disturbance of the sample.

7. Preparation for Shipment

7.1 Upon removal of the tube, measure the length of sample in the tube. Remove the disturbed material in the upper end of the tube and measure the length again. Seal the upper end of the tube. Remove at least 1 in. of material from the lower end of the tube. Use this material for soil description in accordance with Practice D 2488. Measure the overall sample length. Seal the lower end of the tube. Alternatively, after measurement, the tube may be sealed without removal of soil from the ends of the tube if so directed by the engineer or geologist.

NOTE 5—Field extrusion and packaging of extruded samples under the specific direction of a geotechnical engineer or geologist is permitted.

NOTE 6—Tubes sealed over the ends as opposed to those sealed with expanding packers should contain end padding in end voids in order to prevent drainage or movement of the sample within the tube.

7.2 Prepare and immediately affix labels or apply markings

as necessary to identify the sample. Assure that the markings or labels are adequate to survive transportation and storage.

8. Report

8.1 The appropriate information is required as follows:

- 8.1.1 Name and location of the project,
- 8.1.2 Boring number and precise location on project,
- 8.1.3 Surface elevation or reference to a datum,
- 8.1.4 Date and time of boring—start and finish,
- 8.1.5 Depth to top of sample and number of sample,
- 8.1.6 Description of sampler: size, type of metal, type of coating,

- 8.1.7 Method of sampler insertion: push or drive,
- 8.1.8 Method of drilling, size of hole, casing, and drilling fluid used,
- 8.1.9 Depth to groundwater level: date and time measured,
- 8.1.10 Any possible current or tidal effect on water level,
- 8.1.11 Soil description in accordance with Practice D 2488,
- 8.1.12 Length of sampler advance, and
- 8.1.13 Recovery: length of sample obtained.

9. Precision and Bias

9.1 This practice does not produce numerical data; therefore, a precision and bias statement is not applicable.

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